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Unannounced evacuation of large retail-stores

An evaluation of human behaviour and the computer model Simulex

October, 1997

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ABSTRACT

Two unannounced evacuations of Marks & Spencer stores were conducted in a large single-story building at Sprucefield, Lisburn and in a three-storey building at Donegall Place, Belfast, Northern Ireland.

The purpose of this report was to collect, compile and evaluate human information with respect to its ability viz. computer simulation modelling, fire regulations and Fire Safety Engineering application.

The evacuations were recorded on video and the evacuees were invited to complete a survey to provide data for analysis. Before the evacuations only the Store manager, his Deputy and the Health & Safety manager in each store knew about the evacuations.

The first part of the study provides results of pre-movement times, occupants familiarity within the building, exit choice and walking speeds. Most results agreed with earlier studies related in the same area. The results may force that the pre-movement times in BSI have to be discussed further.

The evacuations were simulated in computer model Simulex with the results of the first part as input. The second part of the study provides modifications to computer model Simulex that is under development. It also gives suggestions for future improvements of the model. Almost the same results as the real evacuations were obtained in both stores.

SUMMARY

There were 486 occupants in the Sprucefield store and 570 occupants in the Belfast store when the evacuations took place. The evacuation time required for the Sprucefield store was 2 minutes and 45 seconds and for the Belfast store 4 minutes. The suggested recognition time for a W1 (alarm bell) warning system in the draft BSI 96/542892: Fire safety Engineering is six minutes which is a considerably longer time than for the whole evacuation performed by the occupants in the stores. The suggested pre-movement times have to be discussed further. Implemented with staff would be of interest.

A program of research should be undertaken to investigate use of escalators and lifts during an emergency situation. It would benefit occupants with prams etc.

The maximum pre-movement time was in the Belfast store 91 seconds. The mean pre-movement time was in the both stores around 30-40 seconds with a standard deviation around 20 seconds. The prompt action of the staff clearly influenced the occupants pre-movement time observed in the study.

Earlier studies have shown that it is very important to know the buildings internal layout, circulation routes and where to go if an emergency situation occurs. If customers used the store frequently they would be familiar with its internal layout and so was the case here. Around 70% used the stores at least once a time every month. It effected choice of exit. Over 60 % of the customers chose the nearest exit. Most heavily used exits during the evacuation, were the normally used exits for accessing and egressing the buildings.

The prompt opening of exits had a significant effect in the pre-movement time. When the daylight from the outside of the buildings were exposed through the exit the occupants started to evacuate.

Marks & Spencer have a training program for all staff and that was evident in the study. This training helped greatly reduce the evacuation time. A number of situations occurred where staff used a swipe card instead of the panic bolt to open a door. That behaviour must be attended to at once.

Two similar evacuations took place in Marks & Spencer stores in Wales. They had almost the same results. The conclusion is that the human behaviour is not exceptional in Northern Ireland with its 'political' situation.

The simulations performed in Simulex gave a similar result as the actual evacuation. The simulated evacuation took for Sprucefield store 2 minutes and 22 seconds and for Belfast store 4 minutes and 6 seconds. There are some difficulties with the model and it has to be improved to use in large department stores without major problems.

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1 Introduction

One of the main areas of building use and safety research over a period of 25 years has been on human behaviours in fires. Research about how people react and behave during an emergency situation, such as an evacuation of a building caused by a fire, is important to save lives and provide input to different draft codes so that cost effective building design's can be realised.

There are special difficulties in studying human behaviour in evacuation of buildings in emergencies. The causes of these difficulties are that the events concerned are very rare and unpredictable i.e. studies cannot be set up in advance to observe the event when it occurs. People who have had direct experience of being in buildings where there has been a fire, sometimes cannot be questioned immediately and directly because of their traumatic experience /1/. However probably the most prevailing sources of information on human behaviour in fires that has influenced the shaping of the legalisation, are the reports that have emerged from enquiries held after the event.

At present there is concern regarding the potential fire hazard to occupants of public assembly type buildings, e.g. as department stores. Over the years that human behaviour has been studied, very little data and information have been collected on human behaviour in department stores. The reasons are two-fold and substantial resources need to be deployed to obtain information and there have been very few fires where information could have been obtained.

This report observed human behaviour in department stores from unannounced evacuations of two Marks & Spencer stores in Northern Ireland. The evacuations were recorded on video and evacuees were invited to complete questionnaires to provide data for the analysis. Useful human information is collected, compiled and evaluated with respect to its ability, viz. computer simulation modelling, Fire Regulations and Fire Safety Engineering Application.

Limitation

The material presented in this report is based on studies of unannounced evacuations of large retail stores in Northern Ireland. It is confidential and must not be used without the Express permission of Prof. T.J. Shields, Fire SERT, University of Ulster, Northern Ireland. All of the evacuations were made in Mark & Spencer stores where members of staff get education in Fire Safety. People in Northern Ireland, where the unannounced evacuations were made, may be more alert if something abnormal occurs because of the political situation there. The data obtained also does not represent an actual fire situation where the occupants might react and behave with more intensity. The walking speeds obtained were measured from the videotapes given one frame every second; the distances in the store were difficult to measure from the video. In many cases the results of these unannounced evacuations could be used as design values but the designer has to be aware of the limitations presented above.

2 Purpose

The general purpose of this research project was to, obtain human behavioural data in order to characterise the occupancies of large compartment retail stores and to validate the computer model Simulex that might be used for those department stores.

Specifically, the aims of the first part of study was to:

- Obtain and compare the actual performance of the stores in relation to the draft BSI Document 96/542892: Fire Safety Engineering.
- Determine the pre-movement time for people in department stores by department.
- Investigate which exit people choose and why.
- Determine occupant's characteristics in department stores such as alertness, familiarity, mobility, age and gender.

The second part of the study was to:

- Evaluate the computer model Simulex validity in large department stores.
- Give suggestions to improve the computer model to do it user-friendlier.

3 Literature review

3.1 Introduction

The literature reviewed in this chapter is intended to give a brief outline of previous studies of Human Behaviour. There have been a number of previous investigations with the purpose of studying human behaviours in emergency situations. Such research was undertaken in the hope that knowledge gained would decrease risks to people involved in fires. It also examines how attempts at predicting factors such as pre-movement time may be incorporated into Fire Engineering codes. There have been different techniques used to study the way people behave in evacuations. The methods have reach from studying past events to pure laboratory experiments.

Movement towards the Familiar, Person and Place Affiliation in a Fire Entrapment setting. /2/ Sime Jonathan D.

In this book J.D Sime tests the affiliation model. The model predicts that in a situation of potential entrapment people would move towards the familiar i.e. towards persons or places that are familiar.

Sime describes a relationship between the physical availability and nearness of an emergency route and its frequent use. For this affiliation model, statistical interrelationships were found. The study showed that staff left by the fire exit cause they were familiar with it and public moved toward entrance and place affiliations.

The affiliation model assumes that pattern of movement both toward and away from the threat (smoke, fire etc.) is mediated by the degree of familiarity of the individual with other persons and places. It predicts that in an emergency situation, such as in an evacuation of a building, people are even more likely to be drawn towards the familiar than in normal circumstances. The concluding remarks from Sime was that the direction of movement will depend and relate on four major things: The location of the fire, the location of the individual, the degree of familiarity and objects such as group of members and places of affiliations.

Familiarity with escape routes seem to be at least as important as travel distance as a determinant of people’s direction of movement. There also appears to be strong relationship between the normal routes of circulation in the building and those used most in evacuations. Those routes that are only to be used in emergency situations will only be used if it is exposed with a good sign or by staff's directions.

Escape Behaviour in Fires and Evacuations. /3/, Sime Jonathan D.

This paper looks at research on people escape behaviour in fires and evacuations are essential in fire safety engineering design. Most reports on fires make very little or no reference to the affect of fire on human behaviour. Sime suggests that it is at least important to study human behaviour, as it is to study research into smoke, fires spread and fire protection systems etc. This paper considers that there are two very different ways to model (predict, describe and explain) people moving around buildings.

Model A

Model A is the model that describes movement. The model is sometimes called the engineering model and is the physical science of human behaviour. It models people as static or dynamic non-thinking objects. It is the pre-dominant model of escape behaviour in fire codes, engineering and media coverage of fires. The time to escape assumes to be determined primarily by the fire scenario, the objective risk, population size and the physical accessibility of the means of escape. Various assumptions in this model are:

1. Peoples safety can not be guaranteed since in certain circumstances they panic leading to inappropriate behaviour.
2. Individuals start to move as soon as they hear an alarm.
3. The time taken to evacuate a floor is primarily dependent on the time it taken physically to move to and through an exit.
4. Movement in fires is characterised by the aim of escaping.
5. People are most likely to move towards the exit that they are nearest to.
6. People move independently of each other.
7. All the people present are equally capable of physically move to an exit.

Model B

Model B assumes that the time for escape is characterised by the occupants behaviour i.e. the time it takes people to start move and then move, the warning system, perceived risk and a number of social and psychological criteria. Criteria described above can be group ties and roles within the building etc. The results from the research of human behaviour is:

1. Death in large scale fires attributed to panic are far more likely to have been caused by delays in people receiving information about fire
2. Fire alarm cannot always be relied upon to prompt people to immediately to move to safety.
3. The pre-movement time is just as important as the time it takes to physically reach an exit.
4. Much of the movement in the early stages of fires is characterised by activities such as investigation and not escape.
5. Individuals often move towards and with group or family members and maintain proximity as far as possible with individuals to whom they have emotional ties.
6. People's ability to move towards exits may vary considerably (e.g. young fit adult compared to a person who is elderly or disabled).
7. People are often prepared, if necessary, to try to move through smoke.

To Prevent 'Panic' in an Underground Emergency: Why not tell people the truth? /4/ Proulx Guylene & Sime Jonathan D.

The research study was carried out on behalf of Tyne and Wear Passenger Transport Executive in Newcastle, U.K. It was to assess the efficiency of their communication system in the event of an emergency evacuation.

The first stage of the research was to evaluate the day to day functioning of the sub-surface station. The second stage of the study was to evacuate the station. In the past managers of public buildings had considered that in the event of an emergency it is better not tell people the truth if panic is to be avoids.

Stage 1

The analysis showed that generally the Metro had excellent qualities of simplicity, coherence and reliability. The station was easily accessible and accommodated a large proportion of passengers daily who were elderly and wheelchair users. The only problem that was found was that passengers unfamiliar with the Metro had difficulties with understanding the ticket system.

Stage 2

In the second stage five evacuations was carried out in the most spatially complex station. The information given to users in each of the five evacuations differed:

1. alarm bell only
2. alarm bell with two members of staff
3. alarm bell and minimal non-directive public announcements
4. alarm bell with two members of staff and directive public announcements
5. alarm bell with improved directive public announcements

Three measures were adopted from each evacuation; the time to start to move, the time to clear the station and the objective appropriateness of the behaviour in term of the potential risk to people. It was found that the use of just an alarm bell was least affective in terms of start to move and overall evacuation time. The use of staff and directional PA announcements were very affective in evacuating the station.

The study highlights the importance of issuing prompt instructions to the public. Telling the people the truth about an incident appears to be the best way to convince them of the gravity of the situation. The best alarm was the PA announcements but it must be clear and easy to understand.

BRE Digest, Human behaviour in Fire. Digest 388 November 1993. /5/

The concluding remarks from this report was that peoples behaviour in fires depend on the roles that they perceive to be relevant to their responsibilities. The paper also concludes that people in an evacuation situation prefer to use familiar routes for escape. People also tend to disregard alarms because of many false alarms and they base their actions on what information they get during the emergency situations. People often do not 'appreciate' the fire until they can see it and even then do not realise what danger it can have. Therefore the communication system is very important.

Observed behaviour in fires:

- People's behaviour in fire depends on the roles that they perceive to be relevant to their responsibility.
- People prefer to use familiar routes for escape.
- People tend to disregard alarms.
- If early clues to fire are ambiguous, people will seek more information on which to base their actions.
- People do not always react in their best interest.

BRE Digest, The Behaviour of people in Fires. /6/, A. W. Williams RIBA and J. S. Hopkinson

The paper reviews the range of peoples' reactions. It has to be considered in the design of buildings and fire legalisation covering them to reduce the effects of smoke and heat to the occupants of a building. The behaviour of the occupants influences the effectiveness of the fire codes.

The socio-economic group of the occupants in residential occupancies has been studied to determine if it has any greater risk than for the majority of the population. Disadvantaged socio-economic groups were found to be at greater risk. The study also revealed that elderly and very young people were at a greater risk. It has also been found, that in real fires, where persons were near the ignition source, they were drunk, asleep, had a mental or physical i.e. was incapable of putting out the fire.

Human Behaviour in Fires: Summary report. /7/, Sime J.D.

This document summarises the findings of the three-year research project on escape behaviour in fires conducted between 1985-1988. The objective of the project was to determine what factors might deter people who are escaping from a fire from using internal escape routes. In addition, the significance of the 'timing' of escape, or when people start to move towards an exit was identified as being of importance.

The research suggested the importance of the following factors in relation to the escape behaviour by individuals;

- the importance of building dimensions
- role of person in building (public or staff)
- floor of location
- knowledge of the fire
- familiarity of route
- smoke development

Most important finding of the research was the fact that the start up time was as (if not more) important as the time it took physically to reach an exit. The research suggested that there was a disproportionate importance on the time to move and exit flow rates in design standards and regulations.

Familiarity with escape route seemed to be at least as important as travel distance as a determinant of peoples' direction of movement. There also appears to be a strong relationship between the normal routes of circulation in a building and those used pre-dominantly in evacuations. The conclusions suggested that there might be inherent problems with emergency escape routes, which are designed only to be used in emergency situations. Far from encouraging a fire exit to be used in an emergency, restrictions on the regular use of a route make it less likely it will be readily used in a fire.

The timing of escape: Exit choice behaviour in fires and building evacuations /8/, Sime Jonathan D. and Kimura M.

J.D Sime and M Kimura studied the choice of exit in evacuations. They studied the Marquee showbar, Summerland fire, Isle of Man, 1973 and evacuations from two theatres.

The Marquee showbar

The Marquee showbar (MBS) was a self-contained rectangular shaped room. The information on the human behaviour came from the police, witnesses and evacuees. Figure 1 shows the exit used by the occupants in the Marquee showbar at the Summerland, Isle of Man. The majority of staff chose to evacuate via the fire exit door. The majority of the visitors evacuated via the entrance door. The results from Sime and Kimura showed a tendency of people moving towards familiar surroundings i.e. moving in familiar directions such as the way they come in or a way they were used to. The results also revealed a tendency of people left in groups i.e. with members of the family or other people that they were social affiliated to.

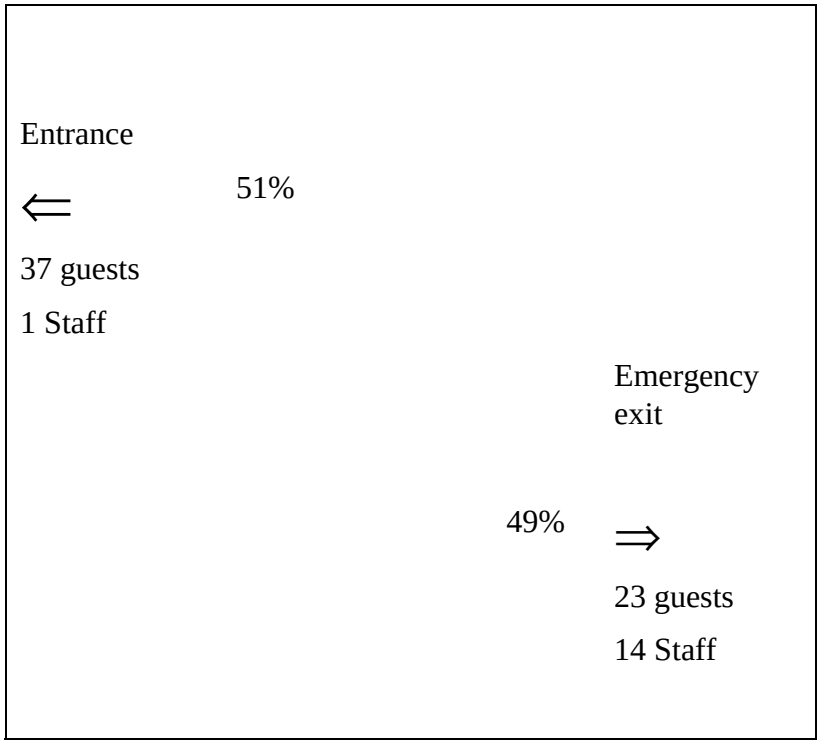

Figure 3.1 Evacuation of Marquee showbar at Summerland, Isle of Man, 1973

Monitored evacuation of two lecture theatres

The two theatres that were studied by Sime and Kimura were experimental and monitored by video cameras. The advantage of monitored evacuations are that the time to escape and direction of movement in response to an alarm can be precisely measured in relation to peoples location. The disadvantage is that there are no flames and smoke, which gives a more realistic scenario. Students and two lecturers occupied the theatres. In the first evacuation of the lecturer directed the students to the fire exit, which did that everyone evacuated via the fire exit. Sime and Kimura means that staffs have a lot of influence over the group they are leading i.e. people evacuate a building via the exit staffs direct them to and not the nearest one. The experiments showed that the familiar exit was chosen. It also showed that the location of the exits were important. In an auditorium it is perhaps better to have the emergency exit at the front of the room so that the listeners sitting in the room can see the exit.

Handicapped people or handicapping environments. /9/, Sime Jonathan D.

Sime evaluated exit choice and evacuation routes in the fire of Woolworth store in Manchester, UK in 1979. The Woolworth store was a three-storey store with a central escalator and two stairwells, figure 3.2. The evacuation routes and the use of them during the evacuation can be seen in table 3.1. The customers in the store used only one of the stairwells, stairwell A, and the escalator to evacuate the building. The reason was that stairwell B was unknown by the customers because the stairwell was only used in emergency situation i.e. the customers had never used stairwell B. The normal route for the customers were stairwell A and the escalator i.e. the familiar route. Staff used every evacuation route that was available because they knew the building and was familiar with its surroundings.

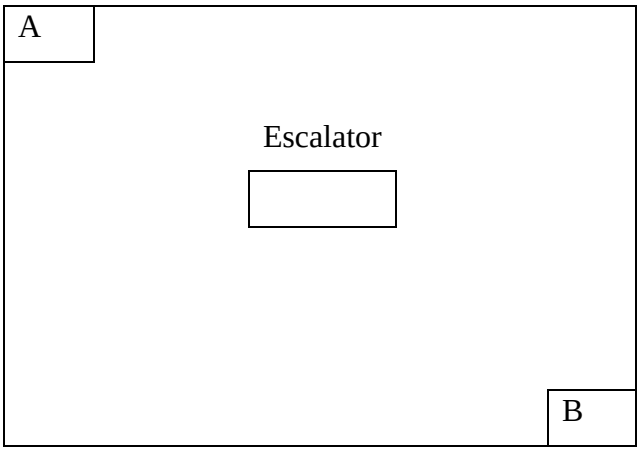

Figure 3.2 Sketch of the floor plans at Woolworth's

Status	Escape route	Percent
Public	Staircase A	71
	Escalator	22
	Window	7
Staff	Staircase A	27
	Staircase B	41
	Escalator	5
	Window	14
	Roof	13

Table 3.1 Evacuation route from the Woolworth store in Manchester

3.2 Concluding remarks

Researches about how people react and behave during an emergency situation in retail-stores are few. It is important that such research is implanted in order to identify and characterise behaviours so that fire codes and computer models can be provided. Evacuations of different public buildings have been done in order to study human behaviour. They have generally been announced i.e. people have been aware that the alarm would occur. It is felt that such drills are not realistic and data gained would not be representative of circumstances occurring in an actual event of a fire. Data from an unannounced evacuation is therefore needed and it is the aim of this dissertation to carry out such research. The main findings of the literature review are listed below:

- A central motivation and activity in fires is to seek information about the nature, seriousness of the situation.
- Social response; people tend to act in-group and not individually.
- People tend to move towards the familiar.
- People's behaviour in fire depends on the roles that they perceive to be relevant to their responsibility.
- Panic is very rare even in very serious fires.
- Education and training are very important i.e. how to react in case of an emergency situation.
- The staffs play a very significant role in evacuations.
- The exit locations are of importance if they are going to be used.

4 Occupants characteristics

4.1 Introduction

The time to evacuate a building is the time taken from the ignition of the fire until all occupants have reached a place of safety. One way of simplifying the evacuation process is to divide it into three different phases:

- Awareness
- Behaviour and response
- Movement

The time elapsed in each phase can be calculated assuming that there are clear distinctions between each phase. The sum of the duration of each phase must be less than the time taken to reach a critical situation e.g. when conditions in the fire spaces became untenable threatened. The procedure must be repeated for each area in the building /10/.

Awareness

Awareness is the time taken from the start of the fire until the occupants of the building become aware that something abnormal has happened /11/. The detection could be in the form of an automatic detection system, smell of smoke, hearing, seeing or through another persons' action. During the awareness period occupants continue with the activities engaged before the signal or alarm. The awareness time in a fire incident can vary greatly depending upon the following factors; the types of building, the nature of occupants, the building alarm and management system /12/. The process can be quite long if there is no automatic detection system present or in buildings where the occupants may be remote from the fire. An example of these buildings can be hostels and hotels. Buildings that are well managed the awareness period are likely to be short.

Behaviour and response

The behaviour and response phase is the period after occupants recognise the alarm or signal and begin to respond to them, but before they taken some actions i.e. evacuate. After the occupants have recognise the alarm or signal that something abnormal has happened they begin to respond to them. The activities undertaken during the response time include /12/:

- investigate what has happened, i.e. seek further information

  (Determine the source, reality or importance of fire alarm)
- help others (seeking and gathering companions)
- save material property (money, other risks)
- try to fight the fire
- call the fire brigade
- leave the building

- ignore the danger
- the time involved in other activities not fully contributing to effective evacuation

This phase can take a considerable amount of time. It should be observed that the time elapsed during the response phase is often longer than the awareness and movement phases.

It is therefore important to investigate this phase further in order to get a reasonable prediction of the total evacuation time.

Movement

The final phase of the evacuation process in this proposed model is the movement phase. The movement time is the time taken from when the occupants start to evacuate until all the occupants have successfully reach a place of safety. The movement time is calculated by summing the different travel times through different building components as the occupants make their way to the final exit. To be able to calculate the movement time it is necessary to know certain data such as /12/:

- Typical walking speeds
- Crowd behaviour in building components
- Nature and number of population in the space
- Number of people likely to use each exit path
- Number of exits which may be unavailable
- Rate of arrival at the exit from the space
- Rate of flow out of the space
- Appropriate subdivision of escape path into zones and sectors
- The evacuations strategy

In many buildings the available exit width may dominate the evaluations and considerations of the distance people have to travel and their movement speeds, become secondary.

Evacuation strategies

There are three main strategies to evacuate a building or to find a safe place during an emergency situation /12/:

- total evacuation
- phased evacuation
- escape to a place of refuge within the building

In the total evacuation strategy the entire premises is evacuated when a fire occurs. The phased evacuation strategy is often used in multi-storey buildings where the fire floor and the floor above are evacuated to maintain control of the evacuation. The escape to a refuge is often used in mines.

The purpose of different evacuation strategies is to ensure that people can leave an area affected by fire before they are subjected to untenable conditions. The choice of strategy must be carefully evaluated and be appropriate to the nature of the building and its occupants. It may not be appropriate to have a total evacuation of a hospital or a similar type of building

because it takes to long time /12/. The strategy used in the unannounced evacuations presented in this report was the total evacuation strategy.

4.2 Characteristics

Occupants have certain characteristics that will influence their ability to response to something abnormal. It is very important that the characteristics are taken into account when calculating the pre-movement time (the sum of awareness and response time). Occupants can be characterised by capability in the pre-movement phase and the movement phase. /13/

4.2.1 Alertness

A major thing is if the occupants are awake or alert when a cue appear /14/. If the people are in bed and asleep or are affected to drugs the alertness to a cue is most likely low. Where narcotics and alcohol been involved in fires a significant fatality have been noted /6/. Most of the public buildings consist occupancies with different aware and alertness.

4.2.2 Mobility

Mobility is for the most people a function of age i.e. the very young and old people have less mobility. Some percent of the population are disabled and may need help to move. Wheelchair users might need help to transfer into the mobility aids. Studies have shown that wheelchair users can take twice as long as those with greater degree of mobility to prepare and start travel to a place of safety /15/. In occupancies such as hospitals many people are temporarily unable to walk and can be relocated by assistance. People there are undergoing medical treatment might have less mobility and need assistance to move. There is also problem with psychiatric institutions and prisons. Therefore, lack of mobility is not necessarily tied up to age, mental or physical capability.

4.2.3 Social Affiliation

People try, as far as possible, to retain contact with their social group such as family and friends when an emergency situation occurs. If parents are separated from their child/children they will most likely try to find them before evacuate. People also seek more information in an emergency situation and they rather move towards the familiar to do that. /2/

4.2.4 Role

If an emergency situation occurs the roles that people normally occupy will have effect on other people. It will most likely shorten the pre-movement time for the people that otherwise would have been confused /8/. Members of staff or other persons that are familiar with the building and its geometry are critically important to the life safety of occupants. If the staff are well trained they can prevent serious injury or death to many people, especially buildings with many visitors for example multi-storey retail stores. For example in the Beverly Hills Supper Club fire where the waitress helped the diners they were serving and not the other tables /16/. When the occupants evacuate the building they will necessarily not go via the nearest exit, they are most likely to use the familiar route for example the route which they entered the building or where the staff directed them to. This is typical in large complexes such as in large stores /9/.

4.2.5 Position

The physical position that people have when an emergency situation occurs will sometimes have great influence on the pre-movement time. The motivation for people that are lying and

have to stand up and start moving towards the exit are less than for people that are already up walking. /14/

4.2.6 Commitment

If the attention of an individual is concentrated towards the task at hand they will tune everything else out. In a case of a fire alarm, the individual will have a delayed awareness since their focus will still be on the activity and will take a longer time to respond. /12/

When people are in the middle of an activity, such as purchasing, queuing, obtain a ticket or eating they may consider the cue to be an inconvenience. In such a case, one may choose to complete their activity before responding to the alarm and increasing their pre-movement time.

4.2.7 Focal point

The pre-movement time will be increased when an individual looks to another person to know how to react to the alarm. This is the case in an environment such as a theatre or a stadium, where the audience is drawn to a specific attraction. The audience, in an emergency situation, will continue to look at the attraction for further instruction and the pre-movement time will increase. /14/

4.2.8 Familiarity

This factor describes that people often tend to move to familiar places during an emergency situation. Every area in a building should have a connection with the procedure that takes place when an emergency situation occurs, specially those areas that are not usually used. Presently, two categories of familiarity in a building are defined /14/. These are exit familiarity and floor layout familiarity. Exits that are normally used in travel routes out of the building are designated as familiar exits. If an occupant is familiar with the floor layout then all possible exits are assumed to be familiar.

4.2.9 Communications

The message from alarm, staff or other people must be perceptible by the ear and distinct so no misunderstanding can occur. If the message is to frequent and complex the pre-movement time will increase and the whole evacuation process will be delayed /14/.

4.3 Occupant profile

The occupant profile is simply a record containing a particular physical attribute and a particular knowledge attribute. Generally it is the building nature that sets the occupant profile. Examples of occupant profiles are wardens, members of staff, residents, visitors and disabled. Buildings with mixed population can require a more detailed profile such as:

- Age, sex and mass/height ratio

  These factors are the most easily identifiable characteristics of an occupant profile and it may affect the alertness and the physical mobility. Statistics shows that very young and very old people suffer higher fatality rates from fires /6/.

- Distribution

  It is important that people can be physical located so people that are not reacting to the alarm can be assisted.

- Occupancy density

  Population density is the number of people that are in the building when the alarm sounds. This is normally expressed as square metres of floor area per person. The greater the number of people is in a given area, the greater potential loss of life /12/. For many buildings the occupant density are permanent such as beds in a hotel or in a hospital. It is more difficult to measure the occupant density in a public building

- Assistance required

  For persons with some sort of disability or persons that are in an unfamiliar surrounding may require some assistance /15/.

- Education and training

  An implement to increase the level of awareness and familiarity in emergency situations is to educate the occupants /16/. If the staffs in a public building are well trained the pre-movement time will most likely be decreased for the rest of the occupants.

5 Method of evacuation studies

5.1 Introduction

To complete this report two different unannounced evacuation were conducted.

1. Marks & Spencer's Royal Avenue store in Belfast
2. Marks & Spencer in Sprucefield, Lisburn

The unannounced evacuations were recorded on videotape and evacuees were invited to complete questionnaires to provide data for the analysis. There were only the stores manager, his deputy and Health & Safety manager who had prior knowledge of the planned evacuation. The staff in the department stores had no knowledge of the evacuation.

The first part of the study was obtained by information from 36 strategically positioned video cameras. The questionnaires were administrated to the evacuees as they exited the building.

By studying the videotapes and distil the useful data, analysing the questionnaires and then compile the data, the human behaviour in the evacuation was evaluated. The results were then compared with regulations and earlier studies.

The second part of the study was done by simulate the evacuations in Simulex as equal as possible. The input to the computer model was selected from the data obtained in the first part of the study such as pre-movement time, amount of people, choice of exit etc. The problems detected during the work were reported to Mr Peter Thompson, who developed and still is developing the computer model so improvement could be done during the work with this report.

5.2 Selection of stores for evacuation studies

The studies took place in Belfast, Northern Ireland in Marks & Spencer stores. Marks and Spencer is the UK's leading retailer and a global retailer of clothing, food items, and household goods, most of which are sold under its St Michael brand. The company operates more than 370 Marks & Spencer brand stores world-wide. Marks and Spencer accounts for about 40% of the UK lingerie market. It also offers customers a range of foods, sells sandwiches and ready-to-go meals, and is the UK's largest retailer of cut flowers. Its financial operations include credit cards, life insurance, and pension funds. The company also operates supermarkets in the US and men's clothing stores in the US and Japan. /17/

They were approached in spring 1995 and agreed to co-operate in a study that might help to further increase the safety of shoppers and staff. Marks & Spencer has a good reputation for staff, welfare and training and every store have a similar standard of evacuation training so that the evacuations could be compared with each other.

5.3 Methods of data capture

Video recording

Marks & Spencer agreed to use their security cameras to provide coverage of the store area. Additional cameras were to be provided by the University of Ulster for areas of interest not covered by the security cameras. It was hoped to use the video material for variety purposes such as pre-movement time, exit flows and evaluations of escalators and stairs. The data captured by the video could also be of interest in some validation of the questionnaires. The recorded data were also used in the evaluation of the computer model Simulex.

Questionnaires

Questionnaires were presented to all the shoppers as they evacuated from the store. A £3 gift voucher was to be offered to those who responded. Information on customers' profiles and their response were asked. This included:

Sex

The question was asked to examine if there were any differences in the response and behaviour of different genders. Earlier studies showed that males tends to take a dominant role i.e. instructing his female partner. Males are also more likely to fight the fire /18/.

Age

This was divided into three categories; under 15, 15-60 and over 60 years. This was to be used in examine different age groups. Earlier studies showed that the very young and old would be less mobile than others and that the state of mind would affect the response time /6/.

Frequency of Visits

This question was divided into four choices for the customers. The data was to be used to examine if familiarity with the store had impact on exits used. Earlier studies revealed that people prefer to use familiar routes for escape in a emergency situation /2/.

Activity

The question was asked in two parts. The first asked question was what activity the person was engaged in prior to the alarm. The second part of the question asked if the person completed the activity just prior to the alarm. It was used just to be able to give some form of measurement of the commitment.

Commitment

The customers were asked how commitment delayed their response to the alarm. Five choices were available ranging from none to total. In the fire at Woolworth's in Manchester a man was warned of the fire but had some of his soup left and wanted to finish it. He died with his spoon in his hand /9/.

Affiliation.

This question was to be used to see if group behaviour differed to that of an individual. Earlier studies showed that people tend to stay in or form groups /8/. It also showed that family groups tend to reassure each other and sought to keep together i.e. people can instead of evacuating move against the flow.

Why respond?

Customers were asked what made them respond to evacuate. There were six different choices available. Earlier studies have shown that type of alarm and the presence of staff are very important factors /19/, /20/.

Location

This was to be used to examine the use of different departments and if there were differences in evacuation cues within the departments as results of staff or available exits. It was also used in the second part of the study to replace the customers and staff into the computer model Simulex.

Exit

The exit used was to be provided by the respondent by a number or an X on the attached plan. It was important so exit choice could be input in Simulex.

Route

This was to get information why the respondent chose a particular route. Earlier studies of escape behaviour suggest that familiar routes are more often chosen /3/.

Stairs

This was to determine means of escape of the vertical evacuation in the multi-storey department store.

Evaluation of the computer model Simulex.

Location and exit choice

The number of customers and staff evacuating through each exit were distilled from the videotapes. The questionnaires gave a percentage of exits used from each department during the evacuation. By scaling the number of people through each exit to each department in the store, the number of occupants at each department was determined.

Pre-movement time

The mean pre-movement time and standard deviations for each department were distilled from the videotapes and input in the computer model.

6 Evacuation of Mark & Spencer store, Sprucefield

The building of Mark & Spencer store in Sprucefield

All departments are on ground level with two stairwells leading to office for staff. In the building there are other stores such as a restaurant, flower shop and a whine shop. Those shops were not included in the evacuation. The Marks & Spencer store have 14 exits, three of which are used as entrances. The main entrances are exit 4, 5, and13. The cameras were positioned close to exits, tills and in isles to provide information of human behaviour. The plan of the building and the camera positions can be seen in figure 6.1.

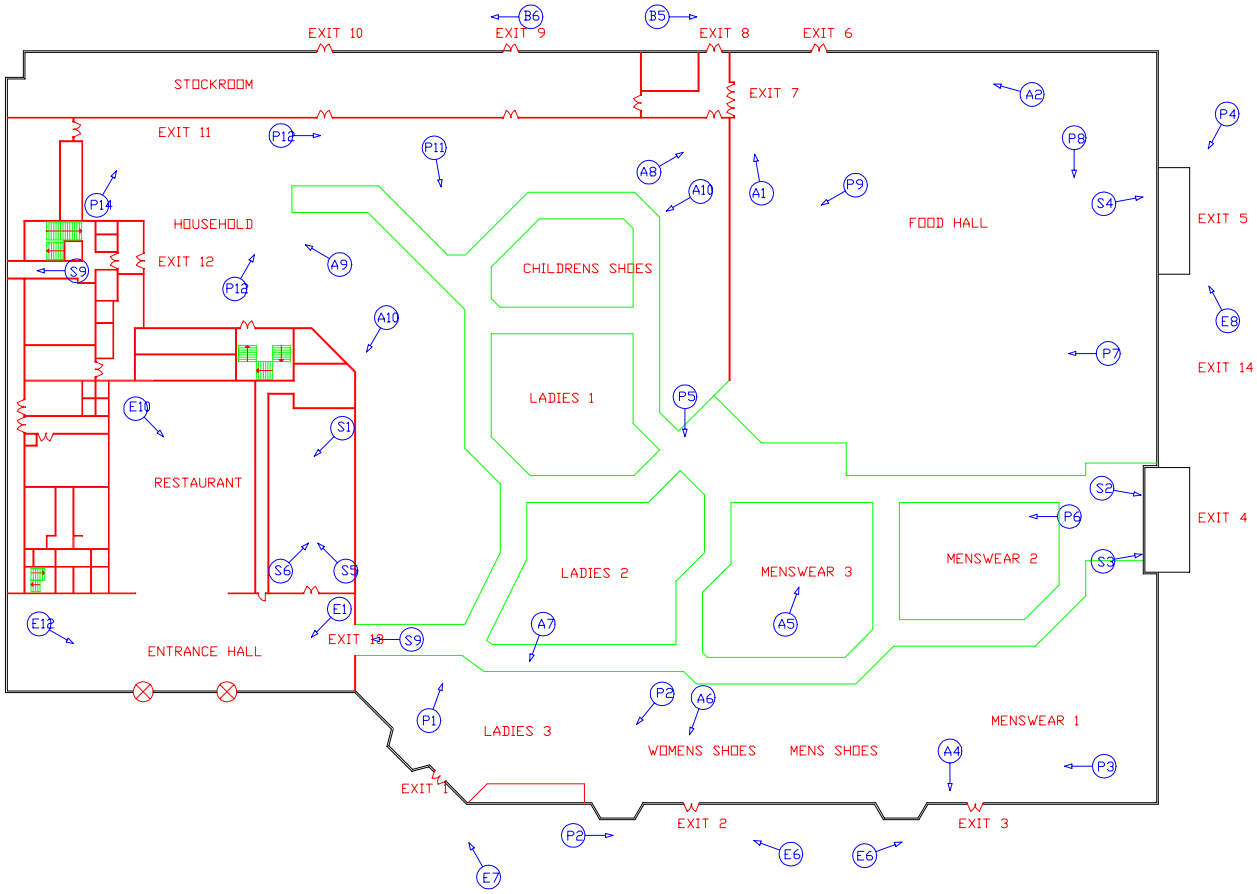

Figure 6.1 The plan over the Mark & Spencer store in Sprucefield with camera positions

7 Analysis of questionnaires, Sprucefield store

7.1 Introduction

The unannounced evacuation was recorded on videotape and from the videotapes it was estimated that 486 occupants were in the store when the evacuation took place. A total of 288 questionnaires (65%) were returned and analysed in this chapter. It shall be noted that the questionnaires were only for the customers.

7.2 Occupants profile and characteristics

Age and Gender

The age and gender of the occupants are presented in table 7.1. The majority of all customers were female (84%). Most of the customers (63%) were also in the age between 15-60 years old and it shall be noted that the people in that group were closer to 60 than to 15 years old extracted from the video tapes. Around 35% of the customers were over 60 years old.

Occupants characteristics	Value Label	Percent (%)
Gender	Male	16
	Female	84
Age	Under 15	2
	15 - 60 years	63
	Over 60 years	35

Table 7.1 Occupants characteristics of gender and age

Social affiliation

During an emergency situation earlier studies showed that people try as far as possible to retain contact with their primary social group such as their family when to evacuate /2/. Table 7.2 shows the social affiliation of the occupants in the store. The questionnaires from this evacuation showed that 77% of the customers were accompanied when they entered the store. Of the 77% that entered the store as a group, 35% were separated when the alarm sounded and of the 35% that were separated 39% tried to re-unite with their group before evacuating.

Occupants characteristics	Value Label	Percent (%)
Social Affiliation	Alone	23
	Accompanied	77

Table 7.2 Occupants characteristics of social affiliation

From analysing the questionnaires some of the customers crossed almost the whole store before finding group member and then evacuated.

Familiarity

Earlier studies have shown that it is very important to know the buildings internal layout and circulation routes and where to go if an emergency situation occurs /21/. If customers used the store frequently they would be familiar with its internal layout and so was the case here. Around 76% used the store at least once a time every month. Table 7.3 shows more in detail how often the occupants visited the store.

Occupants characteristics	Value Label	Valid Percent
Frequency of store use	First visit	2
	1/ week	41
	1/month	35
	2 to 3 times a year	22

Table 7.3 Occupants characteristics of familiarity within the building

In chapter 7.3 where the exit choice was investigated, the familiarity that the customers had with the store will show that the nearest exit was the most chosen escape route.

Occupant density and position by department

There were 486 people in the store, Sprucefield, when the alarm sounded. The density in the store is expressed in terms of m^2 / person. The distribution and occupant density are shown for each department in table 7.4 when scaled up from the questionnaires.

Department	Area ($m^{2)}$	Number of occupants	Percent (%)	Occupant density (m^2 / occupant)
Food hall	2500	186	38	13
Men's wear 1	400	21	4	19
Men's wear 2	180	13	2	14
Men's wear 3	300	11	2	27
Men's shoes	250	4	1	63
Ladies shoes/hosiery	180	28	5	6
Ladies 1	300	49	10	6
Ladies 2	450	55	11	8
Ladies 3	400	32	6	13
Lingerie	500	27	5	19
Children's' shoes	150	6	1	25
Children's wear	600	30	6	20
Household	600	23	4	26
TOTAL	**6810**	**486**	**100**	**14**

Table 7.4 Occupancy density within the store before the alarm sounded

Most of the people in the store, when the alarm sounded, were in the food hall (38%) and in the ladies wear department (32%) i.e. 70% of the total number of occupants were in these two departments. The role that staffs play in emergency situation is important and the information above could be used to place most of the staff in those departments to direct and help customers to evacuate.

The occupant density was within the limit recommended by Approved Document B /22/ and was most densely in the ladies wear departments. The people could during a busy weekend such as around Christmas time increase with a factor of three. The density would still be within the limit recommended in Approved Document B, assuming the same distribution.

Communication

The question of what made them evacuate gave support to earlier findings. The alarm and the members of staff played a very important role in an evacuation situation /23/. Most of the customers (46%) were told by the staff what was going on and there were 33 percent that started to evacuate by the alarm signal, i.e. 79 percent of all customers were in these two groups. In table 7.5 the prompt to evacuate is shown.

Communication	Valid percent
The alarm	33
Public announcement	5
Movement of others towards exit/s	11
Suggestion by companion	1
Direction to evacuate from other shopper	3
Directions to evacuate by staff	46

Table 7.5 The occupants prompt to evacuate

Commitment

When people are in the middle of an activity, such as purchasing, queuing, selecting goods, obtain a ticket or eating they may consider the cue to be an inconvenience /14/. The activity, and if the customers completed their activity during the evacuation is shown in table 7.6.

Activity prior to alarm	Occupants (%)	Complete the activity (%)
Entering	12	33
Walking through/to sales area	8	30
Browsing	21	22
Changing	2	50
Choosing goods to purchase	39	14
Queuing to purchase goods	8	19
Purchasing/paying for goods	8	42
Exiting	2	67

Table 7.6 Occupants completeness to their activity prior to the alarm sounded

The analysis shows in the store and 25 percent of them completed their activity after the alarm sounded. How strong the commitment was varied. The customers completed their activity different due to if staff directed them or not. The people that were not directed by staff or had a companion had more tendencies to complete their activity. Table 7.7 shows the completeness to the occupant's activity due to what kind of cue they responded to.

Communication	Complete the activity	
	Yes (%)	No (%)
The alarm	29	71
Public announcement	33	67
Movement of others towards exit/s	27	73
Suggestion by companion	0	100
Direction to evacuate from other shopper	29	71
Directions to evacuee by staff	19	81

Table 7.7 Occupants completeness of activity compared with the prompt to evacuate

Most effective was the suggestion by companion that had 100 % of prompt to evacuate i.e. no one completed their activity if the suggestion to exit the building came from the companion.

Analysis from the questionnaires showed that the commitment degree did not depend on age and gender. The occupants' commitments to their activity prior to the alarm are shown in table 7.8.

Almost 18% of the people that entered the store were determined to do that and it was all confirmed and captured by the CCTV cameras during the evacuation.

The fact that most of the people had little commitment to their activity might depend on the influence the staff played during the evacuation. They were very effective and directed and helped people out from the store. If the staff had not been at the scene the customers would have had a lot more commitment to their activity.

Commitment / Activities	Not at all (%)	Very little (%)	Some (%)	A lot (%)	Completely (%)
Entering	52	24	6	6	12
Walking through/to sales area	26	39	35	0	0
Browsing	21	47	26	3	3
Changing	50	0	33	17	0
Choosing goods to purchase	21	49	22	4	4
Queuing to purchase goods	32	32	14	13	9
Purchasing/paying for goods	21	54	17	0	8
Exiting	83	0	0	17	0

Table 7.8 Commitment rate of the occupants

7.3 Exit choice

Sime and Kimura have studied the choice of exit /8/. They saw a connection with the way occupants entered the building and the exit choice made in evacuations. In the unannounced evacuation of Marks and Spencer store in Sprucefield the staff played a very significant role. Table 7.9 shows the reason of exit choice by the customers. Around 10% used the exit they entered the store with and 3% used the exit they were familiar with. That is a smaller amount than expected but it shall be noted that the staff directed over 26 percent of the customers to a certain exit. Of more importance was that staff opened the exit doors very early so that daylight could come in. The daylight led the customers to the nearest exit which supports Frantzich /11/. Therefore did over 60 % of the customers chose the nearest exit on the survey while it might have been one of the other alternative if the staff would not have interfere.

Reason for the exit choice	Occupants (%)
It was the way I came in	10
It was a familiar entrance	3
It was the nearest exit	60
I was directed to by staff	26
I was directed to by others	1

Table 7.9 Reason for exit choice by the occupants

No difference between gender and age could be determined why using different exits. What could be seen from the survey was that the main paths and entrances were where most of the customers exited of those who answered 'the same way I came in'. It can be very difficult for people that filled in the survey to choose between 'It was the way I came in' and 'It was a familiar entrance' in the questionnaires

Most heavily used exits during the evacuation were the exits that were normally used for accessing and egressing the building. It was especially exits in the food hall. It shall also be noted that some of the exits were in little use during the evacuation. It can partly be explained by few customers were in the area and that member of staff directed customers to heavily used exits. The exits that were less used than the others did not lead directly to the outside of the building and can there by explain the staff’s acting in the evacuation.

Occupant familiarity -choice of exit

From the questionnaires it can be seen that seven people visited the store for the first time. Table 7.10 shows their choice of exit and why they chose it.

Reason for the exit choice	Occupants
I was directed by staff	4
It was the nearest exit	2
It was the way I came in	1

Table 7.10 Reason of exit choice for the occupants that first visited the store

Staff directed most of these seven people and it would have been interesting to see what reason customers would have had if the staff did not have interfere during the evacuation. The customers who chose the nearest exit were the exits staff opened early in the evacuation. The conclusion is that the staff had influence on those people too.

8 Analysis of video recorded data, Sprucefield store

8.1 Introduction

The unannounced evacuation was recorded on videotape by 30 CCTV cameras and from the videotapes it was estimated that 486 occupants were in the store when the evacuation took place. Appendix A contains occupant's activity, action and observations distilled from every single camera during the evacuation of the store.

The gender, ages, distribution, travel speed and if they were customer or staff were captured on the video. It shall be noted that the age and travel speed were difficult to determined so the reader should know the limitation of it. From the videotapes a number of 176 occupants were captured at the start or just after the alarm sounded.

8.2 Occupants profile and characteristics

Age and Gender of customers

Table 8.1 shows the predicted age and the actual gender distilled from the videotapes. The majority of all the customers were female (72%). Most of the customers (85%) were also in the age between 15-60 years old and it shall be noted that the people in that group were closer to 60 than to 15 years old and some of them might have been over 60 years old. Around 13% of the customers were over 60 years old.

Occupants characteristics	Value Label	Percent (%)
Gender	Male	28
	Female	72
Age	Under 15	2
	15 - 60 years	85
	Over 60 years	13

Table 8.1 Occupants characteristics age and gender distilled from the videotapes

Mobility

The average age of the occupants within the store was between 50 and 60. Generally the mobility of the occupants was good. Analysing the videotapes following exceptions were captured by camera A2, A4 and P13, appendix A.

- Disabled wheelchair user exits via exit 7
- Disabled wheelchair user needed assistance descending a step
- Disabled wheelchair user entered just after alarm

Alertness

The alertness in the store was high; i.e. there was no sleeping risk. The high level of alertness may be a result of that the occupants felt a bit of inconvenience when the alarm sounded. Camera P1 and S9, appendix A, captured an extra high level of alertness.

- Mother and child reacted instantly, without staff intervention.
- Woman reacted almost instantly, without staff intervention.

Communications

In some occasion's individual customers both ignored the alarm or staff and continued browsing. The customers also tended to watch other customers before deciding what to do. The explanation might be that no one wanted to make any mistake if it was a false alarm. The customers also responded to the alarm later than staff members did. It is therefor very important that the staff is determined when telling people to evacuate a building.

The staff was well trained and this training was evident with their confidence directing and helping customers towards exits. This training helped greatly reduce the pre-movement time and the whole evacuation time.

The pre-movement time is the time after an alarm or cue is evident but before the occupants of the building begin to move towards an exit. The mean pre-movement time for the customers that were observed from the videotapes were 32 seconds and the maximum pre-movement time was 87 seconds. The staff that was observed when the alarm sounded had a mean pre-movement time of 22 seconds. The staff played a significant role for the pre-movement time. Where there were no staff interventions the mean pre-movement time for customers were approximately 50 seconds.

The age of the occupants played also a role in the evacuation due to how fast they responded and reacted to the fire alarm. Customers under 15 and over 60 years old did not react and start evacuate as fast as the age group of 15-60 years old. It supports earlier studies made by A W Williams and J S Hopkinson /6/. There was not a significant difference of the pre-movement time by gender in the store.

Table 8.2 shows the pre-movement time for the three different age groups. The group between 15-60 years has a shorter pre-movement time than the other two age groups. It shall be noted that just three samples from the group less than 15 years old could be observed from the videotapes and the author warn the reader for its limitation.

Pre-movement time				
Age	**Mean**	**Maximum**	**Standard deviation**	**Count**
Under 15	39	47	(7)	3
15 - 60 years	31	87	15	121
Over 60 years	38	71	17	19

Table 8.2 Pre-movement time by different age groups

Social affiliation

During an emergency, people will try as far as possible to retain contact with their social group such as family members /2/. Camera A4, P2 and A10, appendix A, captured following behaviour.

- Female re-enters the store over two minutes after the alarm sounded as if she searching for someone.
- Person waits for partner at changing room. They are evacuating together.
- Child lost, helped to safety by staff

During the evacuation a child lost her parent. The child was looking for her parents. The staff helped them to re-unite. The mother had not evacuated. She was looking for her daughter when they re-united.

Physical position

Generally, it takes greater motivation for a person who is lying down or sitting to stand up and begin evacuating the building /14/. There was no one sitting in the store so there was not possible to access the effect of this characteristic.

Commitment

People are action or goals orientated and have reasons for being in a particular place and those reasons will continue to guide their behaviour even when an emergency occurs. The following observations were captured during the evacuation by camera A5, appendix A.

- Person continues browsing (smelling perfume) over one minute after alarm sounded.

Focal point

When the setting has a focal point such as tills and customer service areas, the occupants of the building would normally look towards that point for guidance in the first stage of an alarm. Camera P8 and P14, appendix A, captured the following observations.

- Staff interaction at the tills.

Familiarity and way-finding

The process involved in determining the appropriate means of escape might be influenced by familiarity, group behaviour and staff intervention. As a general rule occupants will only use an exit which is familiar to them, unless they not are instructed /16/. Camera A6, A7, A8, P13 and A9, appendix A, captured the following observations.

- Customer opened door, not staff.
- Customers moved to main exit and not to the nearest exit.
- Staff opened door to exit 8 and guided out customers.
- Staff did not direct customers towards nearest exit.

8.3 Occupants travel speed

Most of the previous studies that have been done have found the various travel speed and flow rates as a function of crowd density /24/. In the store it was obvious that the speed of the occupants decreased a lot when they reached an exit where there was queuing. The mean walking speeds and exit flows for each exit are summarised in table 8.3 and appendix C. The flows and speeds were not exceptional high or low in any part of the store.

Exit	Evacuees			Flow through exit (person/second)		Walking speed (m/s)			
Number	Total	First through exit (sec)	Last through exit (sec)	Mean	Max	Mean	Min	Max	Std
1	33	23	83	0.6	3				
2	62	32	165	0.5	3	0.37	0.2	0.8	0.21
3	28	36	100	0.4	3	0.84	0.2	1	0.36
4	42	32	123	0.5	4	0.82	0.2	1.4	0.46
5	76	17	95	1.0	3	0.57	0.2	1	0.28
6	43	117	153	1.2	3	0.55	0.2	1	0.25
7	(2)								
8	25	31	78	0.5	4	0.57	0.4	0.8	0.15
9	23	24	120	0.2	3				
10	7	48	78	0.2	2	0.8	0.8	0.8	0
11	11	48	96	0.2	2	0.72	0.6	0.8	0.11
12	65	20	117	0.7	3	0.42	0	0.8	0.21
13	38	14	84	0.6	5	1.05	0.8	1.2	0.14
14	31	35	101	0.5	2				

Table 8.3 Flows and travel speeds through different exits

People had generally a higher walking speed when they walked in the isle between the departments than cutting through them. There was also a difference in travel speed for elderly, occupants in wheelchairs and with prams or trolleys etc. As soon as they were assisted out to the isle or left their trolley the walking speed increased. Table 8.4 shows the different walking speeds for occupants observed on the videotape from the evacuation in the store.

Position	**Trolley, wheelchair, or elderly (m/s)**			**No trolley, wheelchair or elderly (m/s)**		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
In departments	0.8	0.6	1.4	1.1	0.6	1.4
Between departments	0.96	0.6	1.8	1.34	0.6	1.8

Table 8.4 Travel speeds for elderly, occupants with trolleys and wheelchairs users

9 Evacuation of Marks & Spencer store, Belfast

The building of Mark & Spencer store, Donegall place, Belfast

The building is from the 1960 and is of steel frame construction. It was extended in the 1980's to a three-storey building. Sales areas are provided on each floor. There are 8 final exits all on ground floor. Two of these exits, exit 1 and 3, are used as public entrances. Access from the basement to the ground floor is by means of 7 staircases and two escalators and one lift. Access from the first floor is by 4 staircases, one escalator and a lift. The plans of the building and the camera positions can be seen in figure 9.1, 9.2, and 9.3 below.

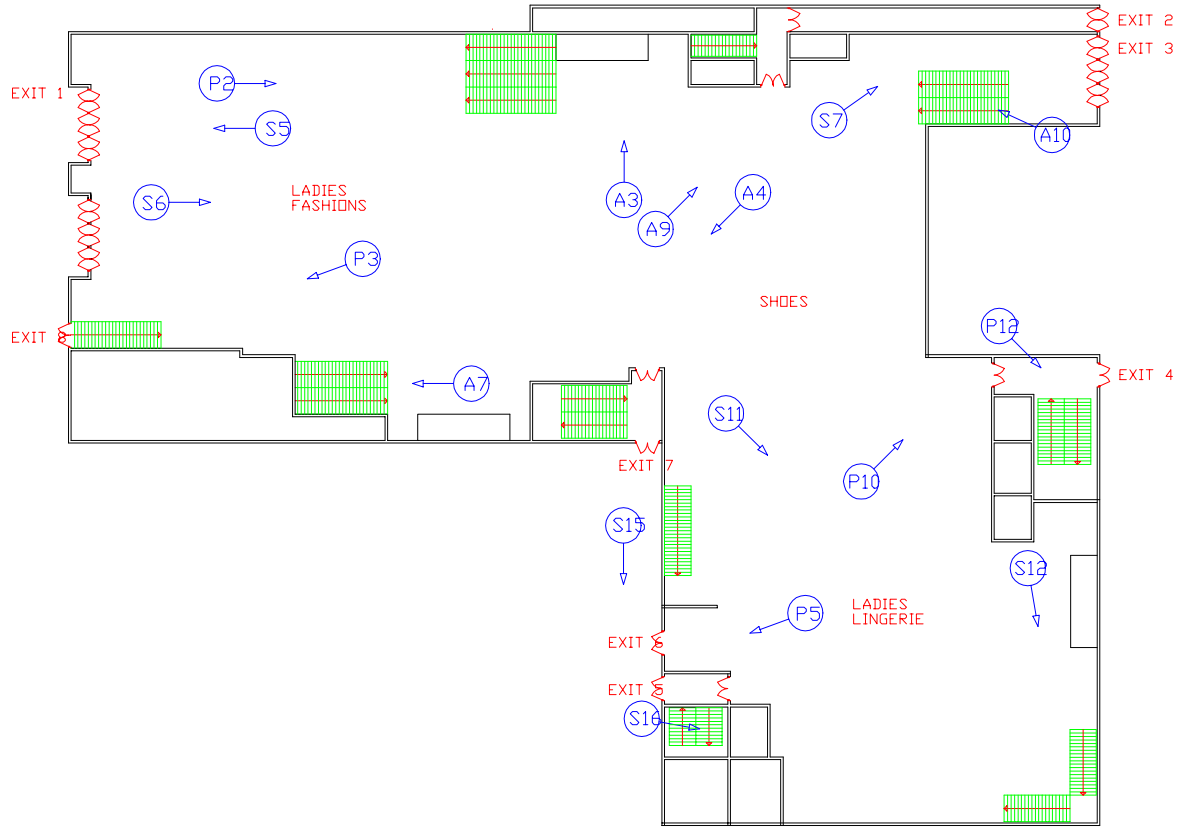

Figure 9.1 Plan and camera position of the ground floor in Belfast store

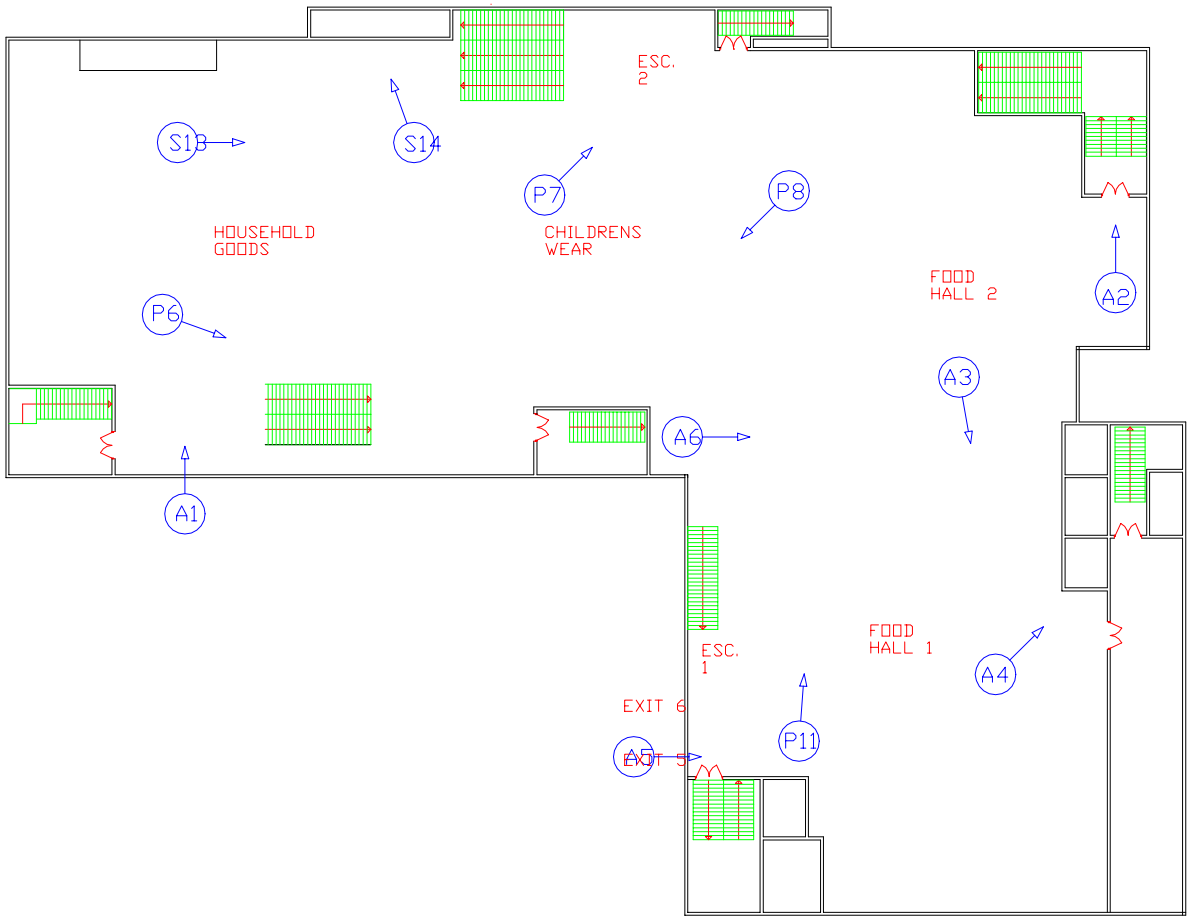

Figure 9.2 Plan and camera position of the basement in Belfast store

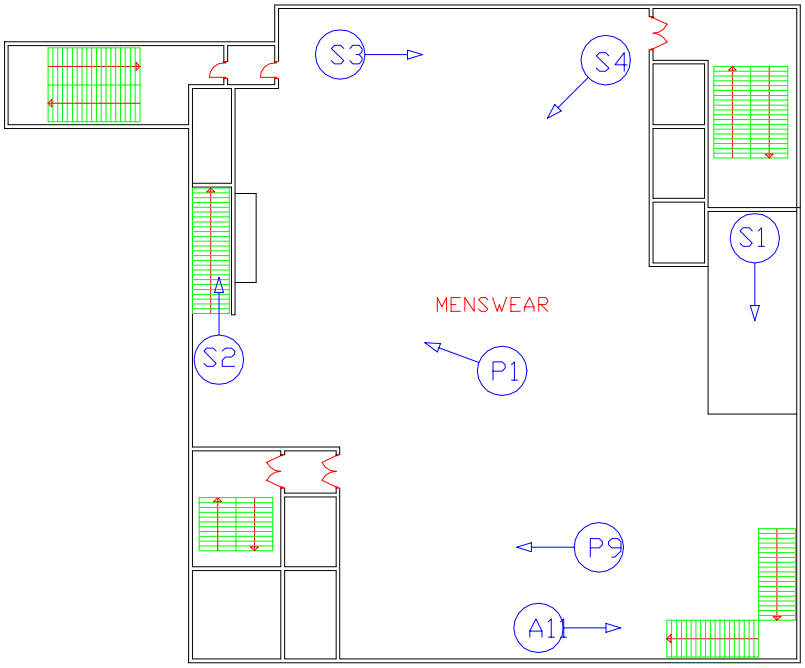

Figure 9.3 Plan and camera position of the first floor in Belfast store

10 Analysis of questionnaires, Belfast store

10.1 Introduction

The unannounced evacuation was recorded on videotape and from the videotapes it was estimated that 570 occupants were in the store when the evacuation took place. A total of 286 questionnaires (55%) were returned and analysed in this chapter. It shall be noted that only the customers answered the questionnaires.

10.2 Occupants profile and characteristics

Age and Gender

The age and gender of the occupants are presented in table 7 below. The majority of all the customers were female (86%). Most of the customers (63%) were also in the age between 15-60 years old and it shall be noted that the people in that group were closer to 60 than to 15 years old distilled from the video tapes. Around 35% of the customers were over 60 years old.

Occupants characteristics	Value Label	Percent (%)
Gender	Male	14
	Female	86
Age	Under 15	2
	15 - 60 years	63
	Over 60 years	35

Table 10.1 Occupants characteristics of gender and age

Social affiliation

During an emergency situation earlier studies showed that people will try as far as possible to retain contact with their primary social group such as their family when to evacuate /2/. Table 10.2 shows the social affiliation of the occupants in the store. The questionnaires from this evacuation showed that 44% of the customers were accompanied when they entered the store. Of the 44% that entered the store as a group, 18% were separated when the alarm sounded and of the 18% that were separated 51% tried to re-unite with their group before evacuating.

Occupants characteristics	Value Label	Percent(%)
Social Affiliation	Alone	56
	Accompanied	44

Table 10.2 Occupants characteristics of social affiliation

From analysing the questionnaires some of the customers crossed almost the whole store before finding group member and then evacuated.

Familiarity

Earlier studies have shown that it is very important to know the buildings internal layout and circulation routes and where to go if an emergency situation occurs /21/. If customers used the store frequently they would be familiar with its internal layout and so was the case here. Around 88% used the store at least once a time every month. Table 10.3 shows more in detail how often the occupants visit the store.

Occupants characteristics	Value Label	Valid Percent
Frequency of store use	First visit	1
	1/ week	69
	1/month	19
	2 to 3 times a year	11

Table 10.3 Occupants characteristics of familiarity within the building

In chapter 10.3 where the exit choice are investigated the familiarity that the customers had with the store will show that the nearest exit was the most chosen escape route.

Occupant density and position by department

There were 570 people in the Donegall store, Belfast when the alarm sounded. The density in the store is expressed in terms of m^2 / person. The distribution and occupant density are shown for each department in table 10.4 below when scaled up from the questionnaires.

Department	Area ($m^{2)}$	Number of occupants	Percent(%)	Occupant density (m^2 / occupant)
Food hall	2000	285	50	7
Men's wear	1000	23	4	43
Shoes	1000	68	12	15
Ladies Fashion	2000	114	20	18
Lingerie	1000	68	12	15
Children's	900	6	1	150
Household	900	6	1	150
TOTAL	**8800**	**570**	**100**	**15**

Table 10.4 Occupancy density within the store before the alarm sounded

Most of the people in the store, when the alarm sounded, were in the food hall (50%) and in the ladies fashion department (32%) i.e. 82% of the total number of occupants were in these two departments. The role that staffs play in emergency situation is important and the information above could be used to place most of the staff in those departments to direct and help customers to evacuate.

The occupant density was within the limit recommended by Approved Document B and was most densely in the food hall. The people could during a busy weekend such as around Christmas time increase with a factor of three. The density in the food hall would not be within the limit recommended in Approvement Document B /22/ in a case of that.

Communication

The question of what made the customers to evacuate gave support to earlier findings i.e. the alarm and members of staff play a very important role in an evacuation situation /23/. Most of the customers (39%) were told by the staff what was going on and there were 31% that started to evacuate by the alarm signal, i.e. 70% of all customers were in these two groups. In table 10.5 the prompt to evacuate is shown.

Communication	Valid percent
The alarm	31
Public announcement	13
Movement of others towards exit/s	15
Direction to evacuate from other shopper	2
Direction to evacuate by staff	39

Table 10.5 The occupant's prompt to evacuate

Commitment

When people are in the middle of an activity, such as purchasing, queuing, selecting goods, obtain a ticket or eating they may consider the cue to be an inconvenience /14/.

The activity, and if the customers completed their activity during the unannounced evacuation is shown in table 10.6. Only 13% completed their activity that was exiting. The other 87% might have been curious and stayed until they were told or found out what was happening. Security staff stopped people from entering the store after the alarm sounded and only 10% entered.

Activity prior to alarm	Occupants (%)	Complete the activity (%)
Entering	7	10
Walking through/to sales area	8	8
Browsing	20	16
Changing	3	3
Choosing goods to purchase	39	30
Queuing to purchase goods	12	9
Purchasing/paying for goods	7	11
Exiting	4	13

Table 10.6 Occupants completeness to their activity prior to the alarm sounded

There were 570 occupants in the store and 28% of them completed their activity after the alarm sounded. How strong the commitment was varied. The customers completed their

activity different due to if staff directed them or not. It seems that the customers ignored the directions from the staff but it shall be noted that the videotapes show the opposite. Table 10.7 shows the completeness to the occupant's activity due to what kind of cue they responded to.

Communication	Complete the activity	
	Yes (%)	No (%)
The alarm	30	70
Public announcement	15	85
Movement of others towards exit/s	21	79
Suggestion by companion	0	100
Direction to evacuate from other shopper	1	99
Directions to evacuee by staff	33	67

Table 10.7 Occupants completeness of activity compered with the prompt to evacuate

Analysis from the questionnaires showed that the commitment grade did not depend on the age and gender. The occupants commitment to their activity prior to the alarm sounded are shown in table 10.8.

Almost 21% of the people that entered the store were determined to do that and it was all confirmed and captured by the CCTV cameras during the evacuation.

The fact that most of the people had little commitment to their activity might depend on the influence the staff played during the evacuation. They were very effective, directed and helped people out from the store. If the staff had not been at the scene the customers would have had a lot more commitment to their activity.

Commitment / Activities	Not at all (%)	Very little (%)	Some (%)	A lot (%)	Completely (%)
Entering	21	32	26	16	5
Walking through/to sales area	27	32	27	14	0
Browsing	32	27	32	5	4
Changing	0	50	25	12	13
Choosing goods to purchase	24	47	19	5	5
Queuing to purchase goods	39	33	24	0	4
Purchasing/paying for goods	37	11	37	5	10
Exiting	64	9	9	0	18

Table10.8 Commitment rate of the occupants

10.3 Exit choice

Sime and Kimura have studied the choice of exit /8/. They saw a connection with the way occupants entered the building and the exit choice made in evacuations. In the evacuation of the store in Belfast staff played a very important role. Table 10.9 shows the reason of exit choice by the customers. Around 18% used the exit they entered the store with and 12 percent used the exit they were familiar with. That is a smaller amount than expected but it shall be noted that the staff directed over 31% of the customers to a certain exit.

Reason for the exit choice	Occupants (%)
It was the way I came in	18
It was a familiar entrance	12
It was the nearest exit	30
I was directed to by staff	31
I was directed to by others	9

Table 10.9 Reason for exit choice by the occupants

No difference between gender and age could be determined why using different exits. What could be seen from the survey was that the main paths and entrances were where most of the customers exited of those who answered 'the same way I came in'. It can be very difficult for people that filled in the survey to choose between 'It was the way I came in and It was a familiar entrance'.

Most heavily used exits during the evacuation were the exits that were normally used for accessing and egressing the building. It was especially the main entrance. It shall be noted that some of the exits were in little use during the evacuation. Partly explained that few customers were in the area and that members of staff directed customers towards heavily used exits. The exits that were less used than the others did not lead directly to the outside of the building and can there by explain the staff’s acting in the evacuation.

Occupant familiarity -choice of exit

From the questionnaires it can be seen that three people visited the store for the first time. Table 10.10 shows what reason the first visitors had for their exit choice.

Reason for the exit choice	Occupants
I was directed to by staff	1
It was the way I came in	2

Table 10.10 Reason of exit choice for the occupants that visited the store for the first time.

It was the familiarity within the store and the staff that made them chooses exit. It gives support to earlier findings by Sime and Kimura /8/.

11 Analysis of video recorded data, Belfast store

11.1 Introduction

The unannounced evacuation was recorded on videotape by 36 CCTV cameras and from the videotapes it was estimated that 570 occupants were in the store when the evacuation took place. Appendix B contains occupants' activity, action and observations distilled from every single camera during the evacuation of the store.

The numbers, gender, age, distribution, travel speed and if they were customer or member of staff were captured on the video. It shall be noted that the age and travel speed were difficult to determined so the reader should know the limitation. From the videotapes a number of 170 occupants were captured at the start or just after the alarm sounded.

11.2 Occupants profile and characteristics

Age and Gender of customers

Table 11.1 shows the predicted age and the actual gender distilled from the videotapes. The majority of all the customers were female (77%). Most of the customers (60%) were also in the age between 15-60 years old. It shall be noted that the people in that group were closer to 60 than to 15 years old and some of them might have been over 60 years old. Around 38% of the customers were over 60 years old.

Occupants characteristics	Value Label	Percent (%)
Gender	Male	23
	Female	77
Age	Under 15	2
	15 - 60 years	60
	Over 60 years	38

Table 11.1 Occupants characteristics age and gender distilled from the videotapes

Mobility

The average age of the occupants within the store was between 50 and 60. Generally the mobility of the occupants was good. Analysing the videotapes following exceptions were captured by camera P2, S16 and P12. (Appendix B)

- Three children in prams had to be assisted ascending the escalator by staff.
- Disabled wheelchair user enters lift to escape with assistant.
- Disabled wheelchair user is assisted to escape up the stairs.
- Old man with a stick is assisted up from basement towards the exit.

Alertness

The alertness in the store was high; i.e. there was no sleeping risk. The high level of alertness may be a result of that the occupants felt a bit of inconvenience when the alarm sounded. A extra high level of alertness was captured by camera S14. (Appendix B)

- Woman reacted almost instantly, without staff intervention.

Communications

The customers perceived the alarm bell as a unspecified warning signal. In some occasion's individual both ignored the alarm or staff and continued browsing. The customers also tended to watch other customers before deciding what to do. The explanation might be that no one wanted to make any mistake if it was a false alarm. The customers also responded to the alarm later than the staff members did. In some occasion's staff responded late.

The staff was well trained and this training was evident with their confidence directing and helping customers towards exits. This training helped greatly reduce the pre-movement time and the whole evacuation time. The mean pre-movement time for the customers that were observed from the videotapes was 36 seconds. The maximum pre-movement time was 91 seconds. The staff captured from the videotapes when the alarm sounded had a mean pre-movement time of 22 seconds. The staff played a significant role for the pre-movement time. Where there were no staff interventions the mean pre-movement time for customers increased and were approximately 50 seconds.

The age of the occupants played also a role in the evacuation due to how fast they responded and reacted to the fire alarm. Table 11.2 shows the pre-movement time for the three different age groups. The group between 15-60 years has a shorter pre-movement time than the other two age groups. It supports earlier studies made by A W Williams and J S Hopkinson and published in BRE Digest /6/. There was not a significant difference of the pre-movement time between females and males in the store.

It shall be noted that just two samples from the group less than 15 years old could be observed from the videotapes and the author warn the reader for its limitation.

Pre-movement time				
Age	**Mean**	**Maximum**	**Standard deviation**	**Count**
Under 15	34	38	(6)	2
15 - 60 years	32	110	19	103
Over 60 years	46	91	22	65

Table 11.2 Pre-movement time by different age groups

Physical position

Generally, it takes greater motivation for a person who is lying down or sitting to stand up and begin evacuating the building /14/. The following observations were captured by camera P7. (Appendix B)

- Person sitting down and reading a newspaper is told by staff to evacuate 30 seconds after alarm sounded. The person does not move until three minutes have passed.

Commitment

People are action or goals orientated and have reasons for being in a particular place and those reasons will continue to guide their behaviour even when an emergency occurs. The following observations were captured during the evacuation by camera P7, A3 and A2. (Appendix B)

- Person sitting down and reading newspaper for a long time.
- Person return to collect goods
- Person shopping and alerted by other person to evacuate.

Focal point

When the setting has a focal point such as tills and customer service areas, the occupants of the building would normally look towards that point for guidance in the first stage of an alarm. Camera A6 and P11 captured the following observations. (Appendix B)

- Staff interaction at the tills.
- Staff interaction at the tills.

Familiarity and way-finding

The process involved in determining the appropriate means of escape might be influenced by familiarity, group behaviour and staff intervention. As a general rule occupants will only use an exit which is familiar to them, unless they not are instructed /16/. Camera S3, S1, P9, A11, P4, A9, and A1 captured the following observations. (Appendix B)

- Stairwell 2 not used.
- Stairwell 4 not used.
- People walked past exit 3 to the escalator.
- Only one person used stairwell 3
- Person came out of door at exit 7 and went to another exit.
- Staff failed to direct occupants to nearest exit. Exit 2 not used.
- Stairwell 5 not used.

11.3 Occupants travel speed

Most of the previous studies that have been done have found the various travel speed and flow rates as a function of crowd density /24/. In the store it was obvious that the speed of the occupants decreased a lot when they reached an exit where there was queuing. The mean walking speeds and exit flows for each exit are summarised in table 11.3 and appendix C. Elderly had generally a slower walking speed, especially in the vertical means of escape.

Exit	**Evacuees**			**Flow through exit (person/second)**		**Walking speed (m/s)**		
Number	**Total**	**First through exit (sec)**	**Last through exit (sec)**	**Mean**	**Max**	**Mean**	**Min**	**Max**
1	262	14	221	1.3	10	0.5	0.1	1.2
2	-	-	-	-	-	-	-	-
3	88	14	183	0.5	3	0.7	0.2	1
4	92	38	240	0.5	4	0.8	0.2	1
5	28	92	166	0.4	2	0.8	0.2	1.2
6	68	54	148	0.7	3	0.9	0.2	1.2
7	33	40	120	0.4	2	0.7	0.2	1

Table 11.3 Flows and travel speeds through different exits

11.4 Use of Stairs, Escalators and Lift

People that were on the first floor and in the basement needed to use stairs, escalators or the lift to evacuate. In this chapter the different use of these means of escape are discussed.

Stairs

There were eight stairs in the building. The travel speeds, in the stairs, were between 0.3-0.7 m/s. The fastest occupant was alone in stairwell 6 so there was no obstruction. The slowest travel speed was measured on the wheelchair party ascending stairwell 2. There was not that much difference in travel speed between the evacuees in that stairwell because of the queuing. The travel speeds for the different stairs are summarised in table 11.4.

Stair No	Evacuees from basement	Evacuees from first floor	Travel speed m/s
1	14	-	No data
2	30	32	0.3
3	18	30	No data
4	-	1	0.5
5	-	-	No data
6	1	-	0.7
7	No data	-	No data
8	34	-	0.4

Table 11.4 Occupants and travel speeds in different stairs

Escalators

There were two escalators in the building. Both flights were operational when the alarm sounded. One of the escalators was turned on during the whole evacuation. As a result this was the busiest one. People that were closer to a stairwell used the escalator that was running instead of walking up the stairs. Because the escalator was running and several occupants used it as means of escape, it did not become the fastest way up to the ground floor. People were also carrying bags and prams while ascending and that decreased the speed. The travel speed up and down the escalators was between 0.3-0.9 m/s.

The question is if the escalators should be operating during an emergency situation? The answer is 'Yes'. Even if it is not a faster means of escape the occupant's with prams will have a lot easier to evacuate.

Lift

The lift continued to operate throughout the evacuation. The only persons to use the lift as a means of escape were a wheelchair user and a person that assisted. There was no management of the lift during the evacuation. The two evacuees used the lift and pushed the wrong floor. It can be a devastated mistake in a real fire situation where smoke is involved. The author recommends a staff member to manage the lift during an emergency evacuation so no mistake can be done.

12 Evaluation of computer model Simulex

12.1 Introduction

Once a model is created for a specific purpose, its validity need to be evaluated in terms of its stated purpose. To validate a model means to develop an acceptable level of confidence so that the model can be used and be applicable to the real world. This second part of the study aims at validating the computer model Simulex, an evacuation model developed by Peter Thompson at the University of Edinburgh. To validate and improve the model a meeting with Mr Thompson was settled. During the meeting different difficulties, with the model, were discussed. To evaluate the model, the two unannounced evacuations were used and could work as the answer when comparing the results. During Christmas time the occupant's could increase with a factor of three. That scenario will also be simulated and evaluated.

12.2 Computer model Simulex

Simulex is a computer package for PCs, which is able to simulate the escape movement of many people from large, geometrically complex building structures.

Simulex allows the user to create a 3-D model of a building by using a number of CAD-designed floor plans connected by staircases. Occupants are 'placed' into the building either one-by-one or as groups. The user defines a number of 'final' exits just outside the building, and Simulex will automatically calculate all travel distances throughout the building space. When the building population has been defined, and travel distances calculated, a simulation can be carried out. The user can view an 'evacuation' on-screen and 'zoom' in on areas of interest. It is also possible to record a simulation onto hard disk for later 'real-time' playback. Simulation and animation occurs in time-steps of 0.1 seconds.

The algorithms for the movement of individuals are based on real-life data, collected by using computer-based techniques for the analysis of human movement, observed in real-life footage. These algorithms have produced realistic parameters of motion for individual people moving through different types and geometry of door exits. Simulex models the physical shape and motion of each individual person. Side-stepping and overtaking patterns; speed fluctuations; queuing behaviour; body twisting, and a choice of different exits using the automatic route-assessment functions. /25/

12.3 Peoples characteristics

Walking speed

The walking speed is chosen randomly for each occupant and is in the range from 0.8-1.7 m/s. The walking speed changes as the surrounding conditions change such it does near a crowded exit. The speed is dependent on the interperson distance or distance between occupants. /26/

Physical shape and motion

An individual characteristic that is assigned to each of the building occupants is their body dimension. In Simulex the occupants body dimension, are represented by three circles, as shown in figure 12.1. There are four different body types that are given in the computer model. The body types are shown in table 12.1. /25/

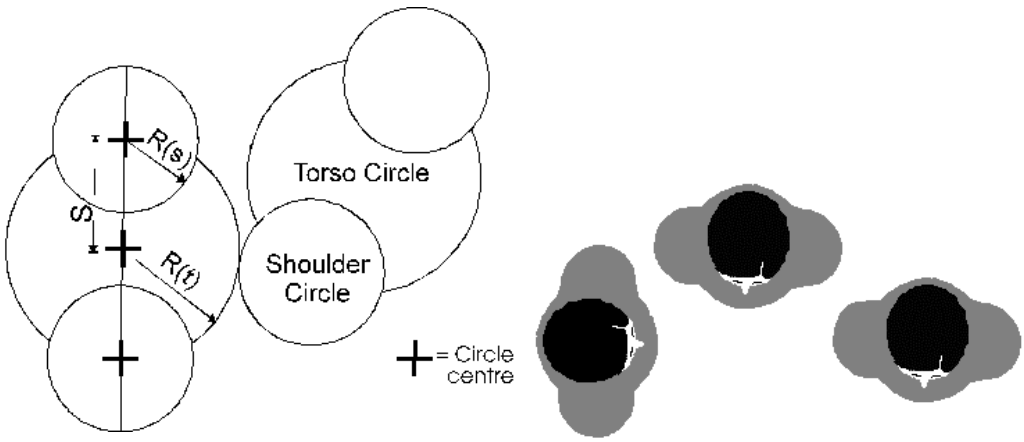

Figure 12.1 Body dimension used in Simulex

Body Type	R(t) (metres)	R(s) (metres)	S (metres)
Average	0.25	0.15	0.10
Male	0.27	0.17	0.11
Female	0.24	0.14	0.09
Child	0.21	0.12	0.07

Table 12.1 Body dimensions used in computer model Simulex

Occupancy type

The occupancy type selected will govern the distribution of body sizes that are assigned to the individuals in the group. The percentage distribution of different body types for different occupant groups are given in the table 12.2 below. /25/

Occupant Type	%'Average'	%'Male'	%'Female'	%'Child'
Office Staff	30	40	30	0
Commuters	30	30	30	10
Shoppers	30	20	30	20
School Children	10	10	10	70
Elderly	50	20	30	0
All Male	100	0	0	0
All Female	0	0	100	0
All Children	0	0	0	100

Table 12.2 Body dimensions in different occupancies.

Pre-movement time

Each occupant can be given a pre-movement time when to start evacuate. This is defined by using one of three distributions. The user specifies the mean response time and the limits (plus or minus a specified amount from the mean) within which the distribution will lie. If random distribution is chosen, then the pre-movement times will be distributed randomly amongst between the limits. Triangular Distribution and Normal Distribution also involve random distribution, but the speeds are distributed with weighting to create the specified distribution type. In the case of the normal distribution, the plus/minus limits represent a value of 3 standard deviations from the mean. /25/

13 Simulation of the evacuations at Marks & Spencer stores

13.1 General

The unannounced evacuations that took place at Marks & Spencer in Sprucefield and Belfast, Northern Ireland were the basis for the input to evaluate the model i.e. inputs such as pre-movement times, occupant distribution, exit choice and occupants characteristics. For both of the stores the occupant's characteristics were ‘shoppers’. In the evacuation of the store in Belfast, a new characteristic was input in the model, That was the characteristic 'elderly'. The actual amount of elderly was input in the simulated evacuation distilled from the questionnaires.

The floor layout for each store were measured and input as a CAD-drawing. There were students on the MSc program in Fire Engineering at the University of Ulster that measured the internal layout. The internal layout can be seen in figure 14.1 for the Sprucefield store and figure 15.1 for the Belfast store.

14 Simulation of Marks & Spencer in Sprucefield

There were 486 occupants in the store when the evacuation took place and the same amount of people was placed in the store when to simulate the event in Simulex.

14.1 Pre-movement times

The pre-movement times were distilled from the videotapes for each department. The people were then placed in the store by the mean and the normal distribution i.e. with the amount of three standard deviations from the mean. Table 14.1 shows the mean pre-movement times and the three standard deviation time from the mean for each department in the store.

The mean pre-movement time by department of the occupants		
Department	**Pre-movement time (sec)**	**Three standard deviations from the mean**
Food hall	38	45
Men's wear 1	20	12
Men's wear 2	23	45
Ladies 1	34	45
Ladies 2	29	15
Ladies 3	30	39
Men's wear 3	26	60
Men's shoes	32	45
Women shoes	29	39
Ladies changing room	50	42
Lingerie	25	33
Household	24	33
Children's wear	30	45
Children's shoes	32	45

Table 14.1 The pre-movement times in different parts of the Sprucefield store

14.2 Distribution and exit choice

The 486 occupants were distributed in each department by the questionnaires and the videotapes. From the videotape the amount of evacuees at each exit were determined. From the questionnaires the percent of occupants at each department using the different exits were determined. By then scaling the amount of people using each exit to the departments the distribution in the store was determined. The distributions and exit choices are shown in appendix D.

At a busy day, such as Christmas time, the amount of people could increase with a factor of three. The Christmas scenario was also simulated. The distribution of the 1458 occupants and their exit choice are shown in appendix D.

The floor layout can be seen in figure 14.1.

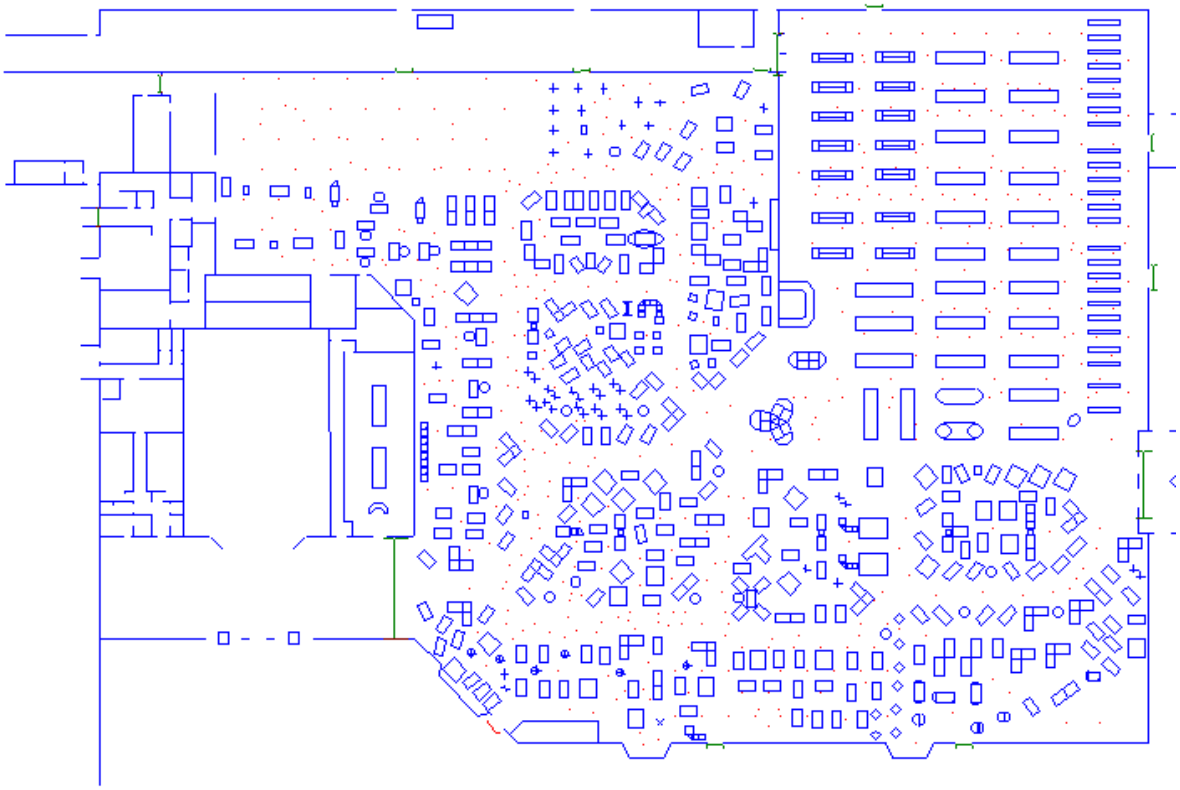

Figure 14.1 The floor layout of the Sprucefield store

14.3 Simulation results of the evacuation

The actual evacuation took 2 minutes and 45 seconds. The computer model with the inputs above gave an evacuation time of 2 minutes and 22 seconds, i.e. very close to the actual evacuation time. The actual evacuation and the evacuation simulated in the model are compared in figure 14.2 every five-second. The flow of evacuees out from the building in the model, is almost the same as in the actual evacuation.

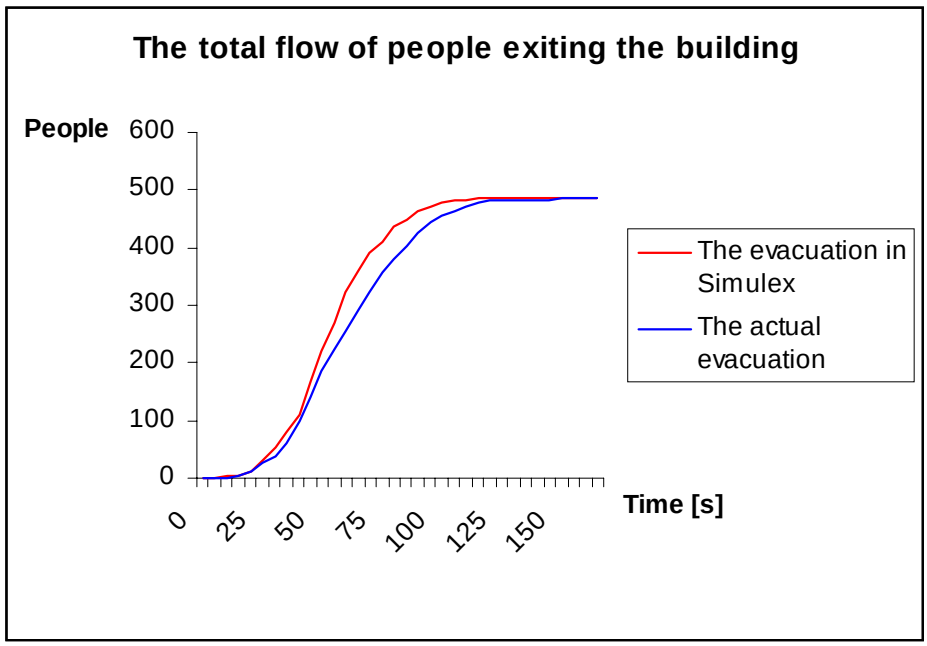

Figure 14.2 The actual and simulated evacuee's flow out from the Sprucefield store

Simulation results of the 'Christmas scenario'

The results from the simulated evacuation of 1458 occupants took 2 minutes and 50 seconds. It is almost the same time as the actual evacuation of 486 occupants. The evacuation time is not dependent on the number of people in the store, because of no bottles-neck at the exits. The depending fact is the pre-movement time in the store. The same pre-movement time was input in both scenarios. This simulation shows that the pre-movement time is the critical time in the store for the whole evacuation time. Figure 14.3 shows the flow out of the building.

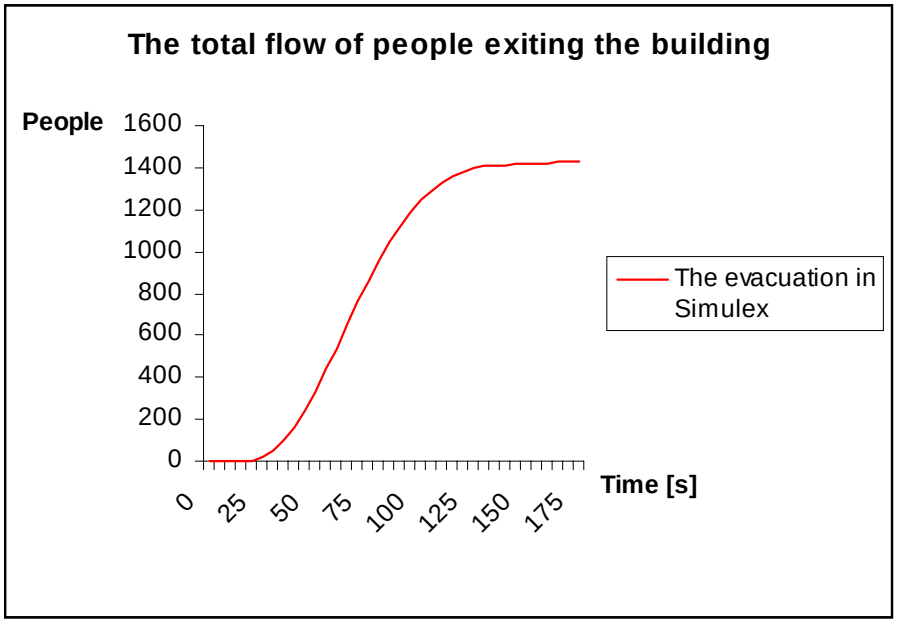

Figure 14.3 The evacuee flow of the simulated Christmas scenario out of from the Sprucefield store

15 Simulation of Marks & Spencer in Belfast

There were 570 occupants in the store when the evacuation took place and the same amount of people was placed in the store when simulating in Simulex.

15.1 Pre-movement times

The pre-movement times were distilled from the videotapes for each department. The people were then placed in the store by the mean and the normal distribution i.e. with the amount of three standard deviations from the mean. Table 15.1 shows the mean pre-movement times and the three standard deviation time from the mean for each department in the store.

The mean pre-movement time by department of the occupants				
	15-60 year		**Elderly**	
Department	**Pre-movement time (sec)**	**Three standard deviations from the mean**	**Pre-movement time (sec)**	**Three standard deviations from the mean**
Food hall	51	75	58	56
Mens wear	30	28	19	38
Household goods	20	2	27	15
Ladies fashions	45	52	45	62
Shoes	24	29	40	12
Ladies lingerie	29	22	26	16
Children's wear	28	23	32	22

Table 15.1 The pre-movement times in different parts of the Belfast store

15.2 Distribution and exit choice

The 570 occupants were distributed in each department by the questionnaires and the videotapes. From the videotape the amount of evacuees at each exit were determined. From the questionnaires the percent of occupants at each department using the different exits were determined. By then scaling the amount of people using each exit to the departments the distribution in the store was determined. The distributions and exit choices are shown in appendix D.

At a busy day, such as Christmas time, the amount of people could increase with a factor of three. The Christmas scenario was also simulated. The distribution of the 1710 occupants and their exit choice are shown in appendix D. The floor layout can be seen in figure 15.1-15.3.

Figure 15.1 The ground floor layout of the Belfast store

Figure 15.2 The first floor layout of the Belfast store

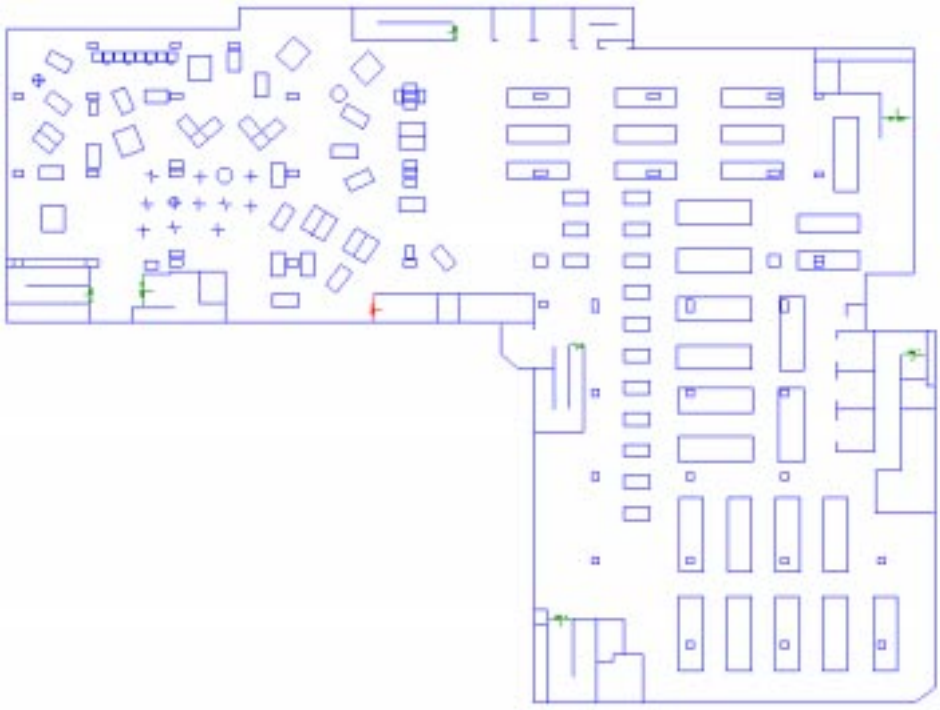

Figure 15.3 The basement layout of the Belfast store

15.3 Simulation results of the evacuation

The actual evacuation took 4 minutes. The computer model with the inputs above gave an evacuation time of 4 minutes and 6 seconds, i.e. very close to the actual evacuation time. The actual evacuation and the evacuation simulated in the model are compared in figure 15.4 every five-second. The flows of evacuees in the model and in the actual evacuation are almost the same.

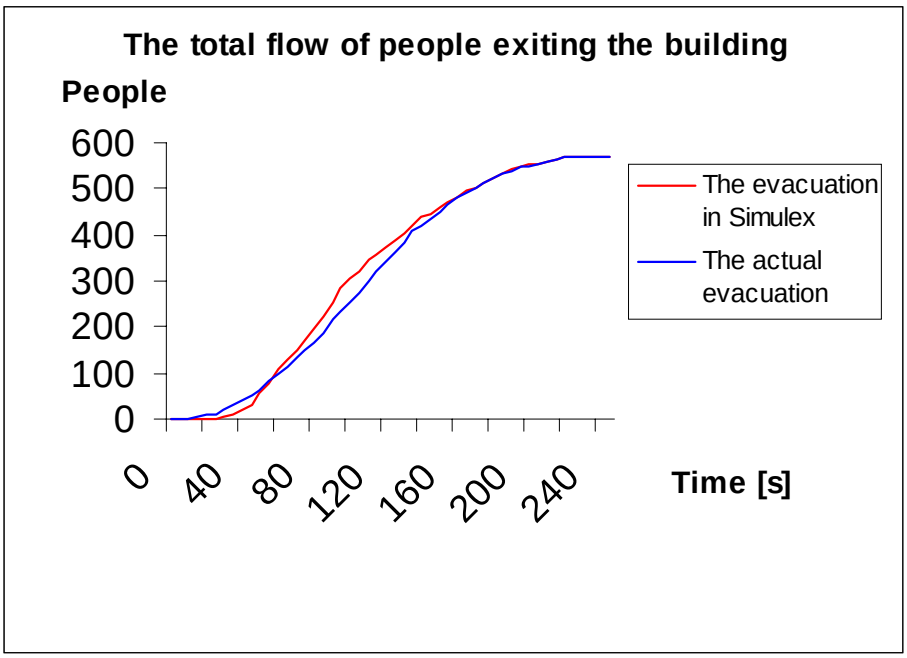

Figure 15.4 The actual and simulated evacuee's flow out from the Belfast store

Simulation results of the 'Christmas scenario'

The results from the simulated evacuation of 1710 occupants did not work. That was because of two factors:

- To many bottlenecks in the internal layout.
- The amount of people.

People got stuck and could not move. When people in the computer meet each other in different situation they start walking in to each other. Because of that no evacuation time could be determined. Figure 15.5 shows different bottlenecks in the store where people got stuck.

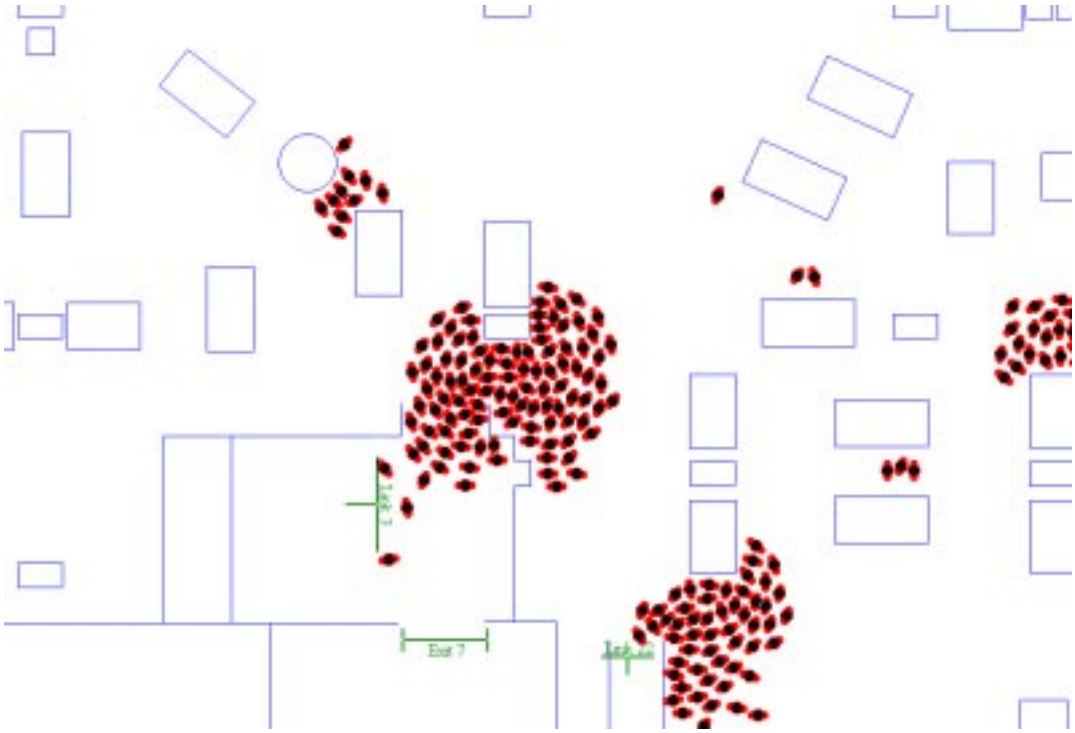

Figure 15.5 The people got stuck in bottlenecks during the simulation of the Christmas scenario.

The computer model Simulex could not handle this simulation this. The computer model Simulex has to be improved so that the problems can be solved in an easier way. The problem that occurred in the simulation of this store occurred also in the other simulation. The difference was that this could not be solved.

16 Modifications to Simulex

The data that Simulex use is accurate but more data need to be considered. During the evacuations of the stores there were problems detected and they are in need to be solved.

Distance maps

When a large retail-store with more than ten exits are simulated, then more than ten distance maps are needed so the user can decide what exits the occupants will evacuate through. The occupants do not always use the nearest exit.

New occupants characteristics

The studies above showed that the majority of the occupants were around 60 years old and older. There were also disabled persons in the store. The computer model does not take any notice of that. It is there for important that new characteristics such as body size and velocity of elderly and disabled persons will be input in the model.

Pre-movement times

The occupants are in the beginning of the evacuation distributed as the 'normal distribution' but later on most of the people beginning to move. A new pre-movement distribution in the model might be needed such as a skew curve. The distributions of the pre-movement time in both stores are shown in figure 16.1.

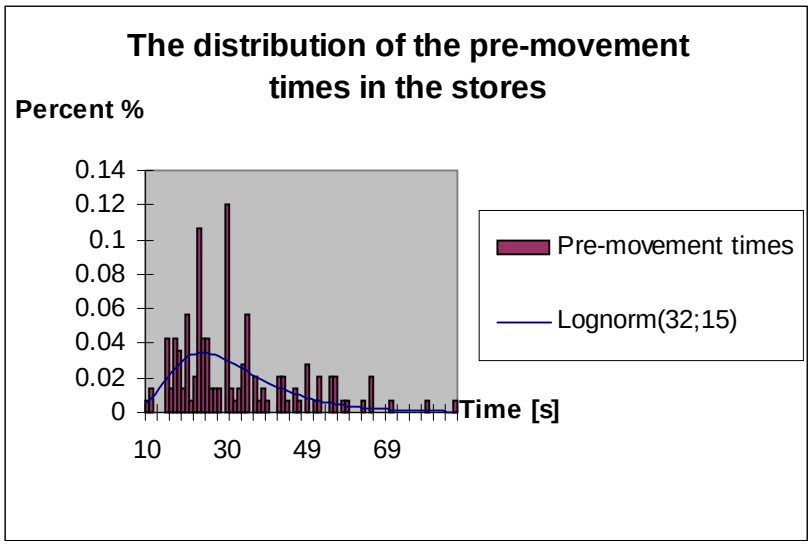

Figure 16.1 The distribution of the pre-movement time

A suggestion is also to randomly issue characteristics for each simulation. Then a more accurately value of the evacuation time can be determined if the mean of ten simulations was picked as the right one.

When the mean pre-movement time is input and the amount of three standard deviations from the mean are higher, i.e. when the mean time minus the three standard deviation time from the mean are negative the evacuation for that person does not work.

Change of occupants' characteristics during simulation

To change characteristics during the simulation would give the model a new dimension. If an exit was unable because of smoke, a new exit could be chosen for that specific distance map

Identify persons with problem

There is very difficult to track people who have a problem and then solve it. By giving the occupants different colours of their different distance maps and their starting co-ordinates the tracking and solving would be a lot user-friendlier.

Occupant problems

During the simulation people met each other in different situations. When the people met where there were narrow space they got stacked. If a parameter is input in the model that says that the occupants get 'invisible' after ten seconds and get through the other occupant(s), a lot of trouble with the model would be solved.

Text-file

The output from the model is poor and is just given the total amount of evacuees out from the building every five second. The text-file should instead give the amount of evacuees per exit every five second.

The information window in Simulex

The information windows provide the user how many evacuees there still are in the building in three places, but not how many that already have been evacuated. An improvement of that could give more information easier.

16.1 Time plan for improvement

Improvements made during the report

- The distance maps have increased from ten to 50.
- Characteristics of elderly with a walking speed of 0.8 ± 0.3 m/s
- Changing the occupants characteristics of a single person or occupants defined in an area without deleting them before the simulation
- Replacement of floor has been corrected. That was an earlier bug detected in the first version of computer model Simulex half a year before this report was made.

Shortcoming improvements

- Different colours to occupants with different distance maps
- The starting co-ordinates for the occupants (original position)
- Change occupants characteristics during the simulation

Future improvement

- Text-file (amount evacuees for each exit)
- Information window (amount people that have evacuated)

17 Conclusions and Recommendations

One of the main areas of building use and safety research over a period of 25 years has been on human behaviours in fires. Research about how people react and behave during an emergency situation, such as an evacuation of a building caused by a fire, is important to save lives and provide input to different draft codes so that cost effective building design's can be realised. Researches about how people react and behave during an emergency situation in retail-stores are few. Evacuations of different public buildings have been done but they have generally been announced i.e. people have been aware that the alarm would occur. It is felt that such drills are not realistic and data gained would not be representative of circumstances occurring in an actual event of a fire. The main findings from the literature review are listed below:

- A central motivation and activity in fires is to seek information about the nature, seriousness of the situation.
- Social response; people tend to act in-group and not individually.
- People tend to move towards the familiar.
- People's behaviour in fire depends on the roles that they perceive to be relevant to their responsibility.
- Panic is very rare even in very serious fires.
- Education and training are very important i.e. how to react in case of an emergency situation.
- The staffs play a very significant role in evacuations.
- The exit locations are of importance if they are going to be used.

17.1 Concluding remarks from Sprucefield store

There were 486 occupants in the Sprucefield store when the evacuation took place. The concluded remarks are listed for the store in this chapter

Questionnaire

There were 288 people that took part in the questionnaire survey. That is approximately 60% of the store population.

Sex

There were 84% females in the store when the evacuation took place.

Age

The main group (63%) of occupants was between 15-60 years old and 35% over 60 years old.

Frequency of Visits

Around 76% of the occupants used the store frequently i.e. they were familiar with its internal layout.

Activity-Commitment

There were different activities in the store when the alarm sounded. Most of the customers (59%) were choosing goods and browsing. The commitment degree to their activity was analysed and 69% had none or little commitment to their activity. The customer's felt that it was more important to evacuate so only 26% completed their activity. The statistical analysis shows that gender and age had little effect on commitment.

Social affiliation

There were only 23% of the occupants that entered the store alone. It might depend on the store geographically orientation. It lies on the countryside. 65% of the occupants that entered the store accompanied were together at the cue and 3% had to find partners before evacuating.

Prompt to evacuate

The majority, 52% of the occupants, was motivated to evacuate by staff. The alarm motivated 32% to evacuate the building.

Location

Most of the customers were in the food hall and the ladies departments when the alarm sounded. The information can be used to direct most of staff to those areas to help and direct customers towards nearest exit.

Exit choice

Over 60% of the customers used the nearest exit and can be explained by the frequency of visit and the staff interventions. Most heavily used exit during the evacuation were the normally used exits for accessing and egressing the building. There were 14% that used the same door as they entered to evacuate.

Video

There were 486 people in the store when the evacuation took place estimated at the final exits.

Pre-movement time

The mean pre-movement time for the customers were 32 seconds and for the staff 22 seconds. The maximum pre-movement time captured was 87 seconds. Where there was no staff intervention, the mean pre-movement time was approximately 50 seconds. Customers between 15-60 years old had a shorter pre-movement time than the younger and older. There was no difference of the pre-movement time by gender.

Use of exits and travel speed

All the exits were used and the last person to leave the building was at 165 seconds after the alarm sounded. Most people were able to leave the building easily. Where there was queuing, the exit flow and the walking speed decreased. People with prams, trolleys wheelchairs and elderly had a slower walking speed. Table 17.1 shows the flows and travel speed through the exits.

Exit	**Evacuees**			**Flow through exit (person/second)**		**Walking speed (m/s)**			
Number	**Total**	**First through exit (sec)**	**Last through exit (sec)**	**Mean**	**Max**	**Mean**	**Min**	**Max**	**Std**
1	33	23	83	0.6	3				
2	62	32	165	0.5	3	0.37	0.2	0.8	0.21
3	28	36	100	0.4	3	0.84	0.2	1	0.36
4	42	32	123	0.5	4	0.82	0.2	1.4	0.46
5	76	17	95	1.0	3	0.57	0.2	1	0.28
6	43	117	153	1.2	3	0.55	0.2	1	0.25
7	(2)								
8	25	31	78	0.5	4	0.57	0.4	0.8	0.15
9	23	24	120	0.2	3				
10	7	48	78	0.2	2	0.8	0.8	0.8	0
11	11	48	96	0.2	2	0.72	0.6	0.8	0.11
12	65	20	117	0.7	3	0.42	0	0.8	0.21
13	38	14	84	0.6	5	1.05	0.8	1.2	0.14
14	31	35	101	0.5	2				

Table 17.1 Flows and travel speeds through different exits in Sprucefield store

The role of management

Marks & Spencer have a training program for all staff within the company and that was evident in the study. The staff directed and helped customers to nearest exits. Security staff was quick to respond by opening exit doors and stop people to enter the building.

In some occasions the staff had difficulties opening exit doors. The staff was using swipe cards to open them instead of using the panic bar. That delayed the evacuation of the building for some evacuees. The staff behaviour can be explained by it was a normally used exit by staff. That behaviour must be attended to at once.

Difficulties by customers

Most people were able to leave the building easily i.e. generally the mobility of the customers were good. There were three disabled wheelchair users in the store. Two of them had problems leaving the store. The first one came to a step and could not descend without being assisted. The second wheelchair user came to a stair just outside exit 12. That wheelchair user also had to be assisted to evacuate. Behind those two wheelchairs users a queue developed and the flow out from the building decreased.

Marks & Spencer have a training program for all staff and that was evident in the study. This training helped greatly reduce the evacuation time. A number of situations occurred where the staff used a swipe card instead of the panic bolt to open the doors. That behaviour must be attended to at once

17.2 Concluding remarks from Belfast store

There were 570 occupants in the Sprucefield store when the evacuation took place. The concluded remarks are listed for the store in this chapter

Questionnaire

There were 286 people that took part in the questionnaire survey. That is approximately 55% of the store population.

Sex

There were 86% females in the store when the evacuation took place.

Age

The main group (63%) of occupants was between 15-60 years old and 35% over 60 years old.

Frequency of Visits

Around 88% of the occupants used the store frequently i.e. they were familiar with its internal layout.

Activity-Commitment

There were different activities in the store when the alarm sounded. Most of the customers (59%) were choosing goods and browsing. The commitment degree to their activity was analysed and 64% had none or little commitment to their activity. The customer's felt that it was more important to evacuate so only 28% completed their activity. The statistical analysis shows that gender and age had little effect on commitment.

Social affiliation

There were over 56% of the occupants that entered the store alone. It might depend on the store geographically orientation. It lies in the city centre. 37% of the occupants that entered the store accompanied were together at the cue and 3% had to find partners before evacuating.

Prompt to evacuate

The majority, 52% of the occupants, was motivated to evacuate by staff. The alarm motivated 30% to evacuate the building.

Location

Most of the customers were in the basement (food hall) when the alarm sounded. The information can be used to direct most of staff to those areas to help and direct customers towards nearest exit.

Exit choice

Over 30% of the customers used the nearest exit and can be explained by the frequency of visit and the staff interventions. Most heavily used exit during the evacuation were the normally used exits for accessing and egressing the building. There were 72% that used those. There were 18% that used the same door as they entered to evacuate.

Video

There were 570 people in the store when the evacuation took place estimated at the final exits.

Pre-movement time

The mean pre-movement time for the customers were 36 seconds and for the staff 22 seconds. The maximum pre-movement time captured was 91 seconds. Where there was no staff intervention, the mean pre-movement time was approximately 50 seconds. Customers between 15-60 years old had a shorter pre-movement time than the younger and older. There was no difference of the pre-movement time by gender.

Use of exits and travel speed

All the exits were used and the last person to leave the building was at 4 minutes after the alarm sounded. Most people were able to leave the building easily. Where there was queuing, the exit flow and the walking speed decreased. People with prams, trolleys wheelchairs and elderly had a slower walking speed. Table 17.2 shows the flows and travel speed through the exits.

Exit	**Evacuees**			**Flow through exit (person/second)**		**Walking speed (m/s)**		
Number	**Total**	**First through exit (sec)**	**Last through exit (sec)**	**Mean**	**Max**	**Mean**	**Min**	**Max**
1	262	14	221	1.3	10	0.5	0.1	1.2
2	-	-	-	-	-	-	-	-
3	88	14	183	0.5	3	0.7	0.2	1
4	92	38	240	0.5	4	0.8	0.2	1
5	28	92	166	0.4	2	0.8	0.2	1.2
6	68	54	148	0.7	3	0.9	0.2	1.2
7	33	40	120	0.4	2	0.7	0.2	1

Table 17.2 Flows and travel speeds through different exits in Belfast store

The role of management

Marks & Spencer have a training program for all staff within the company and that was evident in the study. The staff directed and helped customers to nearest exits. Security staff was quick to respond by opening exit doors and stop people to enter the building.

There was no evidence of management control over the lift during the evacuation. One wheelchair user had their evacuation delayed by almost 2 minutes by that the lift was busy during the whole evacuation.

Difficulties by customers

There was a lot of queuing during the evacuation and that was the problem that occurred in the store. The main exit door seemed to be most queuing. At the escalators some queue developed. If the staff would have direct the customers to stairs where no one used that problem would have been solved. A wheelchair party ascends a stair when the lift did not come. That delayed the evacuation a because there became queuing in the stair.

17.3 Comparison of the studies

The evacuations

Marks & Spencer has a good reputation for staff, welfare and training and every store have a similar standard of evacuation training so that the evacuations could be compared with each other. The population in both stores and the survey were responded similar. There were some differences between the populations' behaviour in the evacuation. Those differences were familiarity, affiliation and exit choice. The reasons for the differences are due to the orientation of the store and its internal layout. The Belfast store is in the city centre and served with public transportation i.e. it is easier for people to go there by them self. Therefore more people were unaccompanied. At Sprucefield, a greater number of the occupants chose to use the nearest exit. That was because the Sprucefield store has twice the number of exits than the Belfast store and the exits were more visual. In table 17.3 the reason for exit choice can be seen for both stores.

Reason for the exit choice	Sprucefield Occupants (%)	Belfast Occupants (%)
It was the way I came in	10	18
It was a familiar entrance	3	12
It was the nearest exit	60	30
I was directed to by staff	26	31
I was directed to by others	1	9

Table 17.3 Reason for exit choice by the occupants in both stores

The evacuations and BSI pre-movement times

The pre-movement time is the time after an alarm or a cue is evident but before the occupants of the building begin to move towards an exit. This consists of two components, recognition and response time. The nomenclature occupant response appears in different draft fire code documents. In some of the draft codes the occupant response receives minimal attention and is more represented in others. The pre-movement time for different occupancy and alarm are tabled in the BSI code and some of them can be seen below in table 17.4. /12, 27/

	BSI document 1996			**Sime's suggestions (BSI 1994)**		
	Recognise time			**Pre-movement time**		
Occupancy	w1	w2	w3	w 1	w 2	w 3
	(minutes)	(minutes)	(minutes)	(minutes)	(minutes)	(minutes)
Hospital	>8	5	<3	8	5	3
Hotels	>6	4	<2	6	4	2
Shopping complexes	***>6***	***3***	***<2***	***5***	***3***	***2***
Offices	>4	3	<1	4	3	1

Table 17.4. Comparison of pre-movement times between BSI 1996 and BSI 1994

The mean pre-movement times for the stores were similar. The mean pre-movement time for the Belfast store was 36 seconds and for Sprucefield store it was 32 seconds. The difference can be the limitation of the video recorded data or more likely to the internal layout in the stores. The Belfast store had high displays in the Food hall department where most people were when the alarm sounded; i.e. staff's action could not be seen.

The suggested recognition time for a W1 (alarm bell) warning system in the draft BSI 96/542892: Fire Safety Engineering code is six minutes which is a considerably longer time than for the whole evacuation performed by the occupants in the stores. *Therefore further discussion of the new times in the draft code are needed and maybe implemented with staff interventions.*

The evacuations and Simulex

The actual evacuation of the Sprucefield store took 2 minutes and 45 seconds. The computer model gave an evacuation time of 2 minutes and 22 seconds, i.e. very close to the actual evacuation time. The actual evacuation and the evacuation simulated in the model are compared in figure 17.1 every five-second. The flows of evacuees in the model and in the actual evacuation are almost the same.

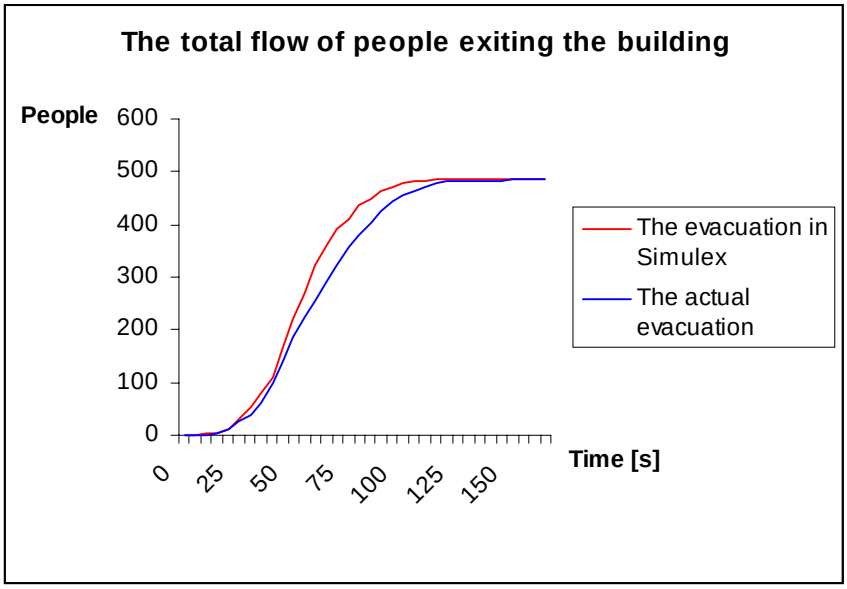

Figure 17.1 The actual and simulated evacuee's flow out from the Sprucefield store

The actual evacuation of the Belfast store took 4 minutes. The computer model gave an evacuation time of 4 minutes and 6 seconds, i.e. very close to the actual evacuation time. The actual evacuation and the evacuation simulated in the model are compared in figure 17.2 every five-second. The flows of evacuees in the model and in the actual evacuation are almost the same.

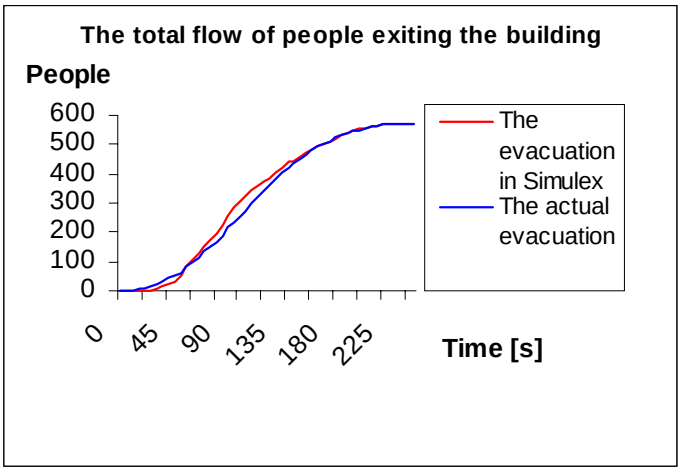

Figure 17.2 The actual and simulated evacuee's flow out from the Belfast store

I shall be noted that the pre-movement time is of great importance. Since the staff action can not be simulated in the model it is of importance that the training level of staff in an building are evaluated before simulated in the program.

17.4 Conclusions

The sound of the alarm and the fast direction by staff made the evacuation of the buildings very quickly. The results clearly demonstrate that the role staff play in an emergency situation such in an evacuation is of great importance. As a result of the evacuation, the pre-movement times were much lower than the suggested in system in the draft BSI 96/542892: Fire Safety Engineering code. *An investigation of the assessments of the pre-movement times and an implement of staff intervention in the in the BSI 96/542892 has to be discussed.*

The height and orientation of displays and different surroundings, e.g. food halls and changing rooms, can affect the pre-movement time of the occupants in an emergency situation. People can become isolated from the staff organising the evacuation in such places. The prompt opening of exits had a significant effect in the pre-movement time. When the daylight was exposed the occupants started to evacuate. *During evenings and nights the exits are recommended to have light outside the door.* When staff use emergency exits as a normal egress route they use their swipe card. That is not to be used in emergency situations and attended to at once.

The majority of people used the escalators to ascend or descend in the multi-storey store in Belfast. It is of concern that many people walked past stairs and escalators that were not operating to use the escalator that still was operating. It is of interest that the travelling speed does not increase with an operating escalator. Escalators that are still operating during an emergency situation can still be of benefit for customers with prams etc. That is of course as long as they do not increase the danger to the occupants. *The use of escalators to facilitate emergency evacuations should be further investigated so that it can be input in fire guidance.*

It can be said that the 'political situation' in Northern Ireland makes people react faster to an alarm in an emergency situation. There were two evacuations made in Wales in two similar stores. Almost the same results were achieved so the results presented in this report are not exceptional, especially for Mark & Spencer stores.

The conclusion for the second part of the study is that Simulex can be used for large retail department stores, but the model is still very time consuming. The use of escalators in the model is not a problem, because the speed is the same as in stairs. *Some improvements have to be done, so that the simulation will operate without major problems*. The suggested improvements are:

Improvements made during the report

- The distance maps have increased from ten to 50.
- Characteristics of elderly with a walking speed of 0.8 ± 0.3 m/s
- Changing the occupants characteristics of a single person or occupants defined in an area without deleting them before the simulation
- Replacement of floor has been corrected. That was an earlier bug detected in the first version of computer model Simulex half a year before this report was made.

Shortcoming improvements

- Different colours to occupants with different distance maps
- The starting co-ordinates for the occupants (original position)
- Change occupants characteristics during the simulation

Future improvement

- Text-file (amount evacuees for each exit)
- Information window (amount people that have evacuated)

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Appendix A

Examples of summery of occupant activities, action and observations distilled from analysis of videotapes in Mark & Spencer, Sprucefield.

Introduction

In this appendix examples of the analysis of the videotaped evacuation is summarised and presented for each camera location and field of view. The use of video gives the pre-movement times, and occupants commitment to their behaviour and data that will be useful for the input in computer model Simulex. The order of cameras is as shown on the videotapes. The camera position is shown in figure A1.

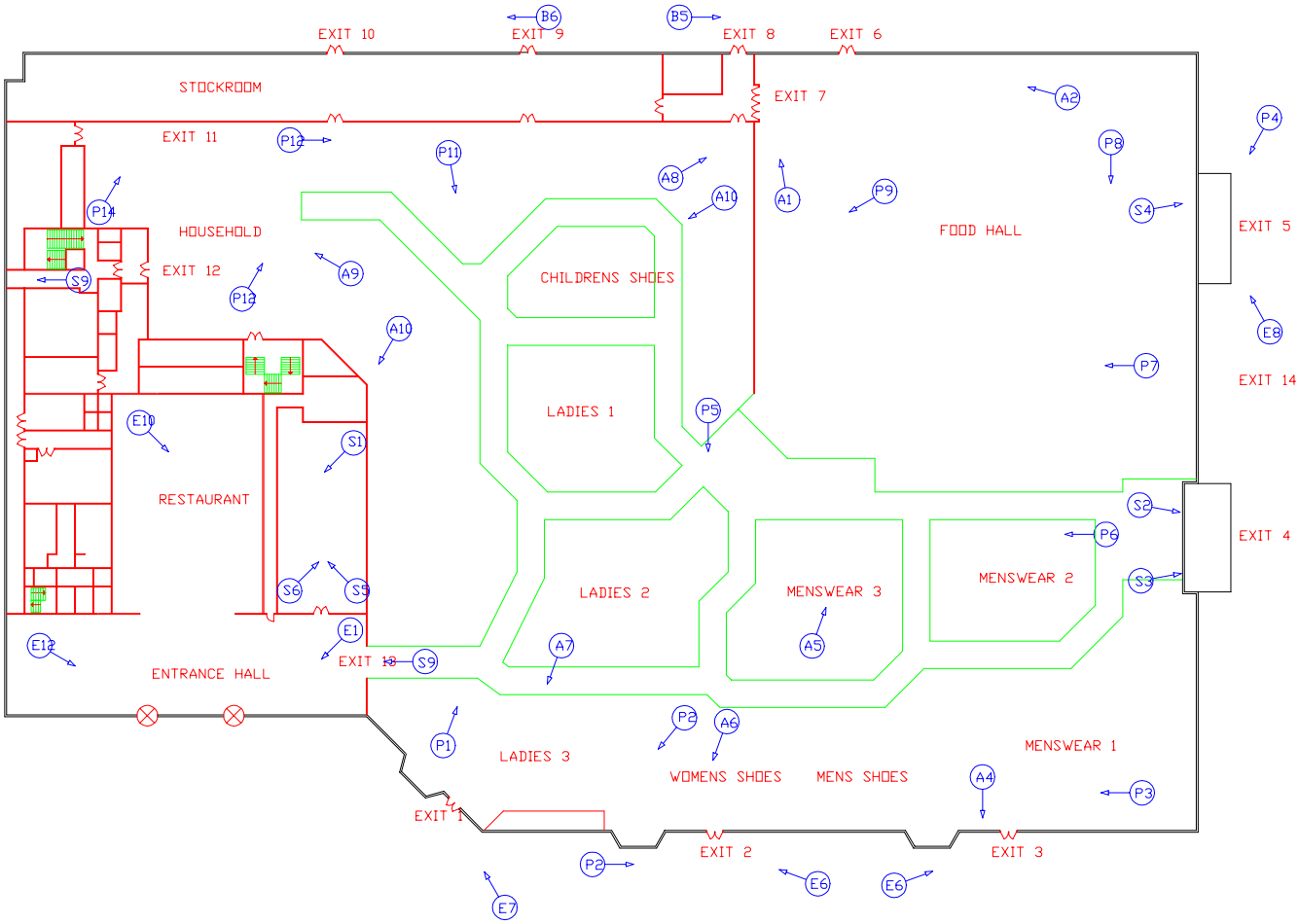


Figure A1 The floor layout and camera position in Mark & Spencer, Sprucefield.

Camera position P8 - Food hall tills

The camera position was at the tills in the food hall. It had a view over the tills, exit 5 and 14. The activities and actions during the evacuation of the occupants are shown in table A1.

Comments

The customers and staff that were purchasing respectively serving were seeking for more information in the beginning. When the supervisor arrived at the tills everything was organised. Most customers and staff that were evacuating through the tills used exit 5 and 14. Some customers used exit 4. The fast reaction from the supervisor and the direction of customer by staff to exits influenced the fast evacuation in this space.

Time (second)	Customer/staff status	Activities	Actions
0	customers and staff members at tills	Customers is purchasing and queuing Staff is serving	
13	customer and staff at tills	purchasing, serving	seeking information
17	supervisor at tills	directing activities to staff at tills	tills closing, directing customers to exits
33	tills closed	beginning to move customers towards exit	customers evacuating
43	staff	sweeping area	walking in to food hall
95	Sales staff	sweeping area	evacuation completed in this part of store

Table A1 Summery of activities and actions of occupants captured by camera P8.

Camera position A2 - Food hall, Exit 6 and 7

The position of this camera was in the food hall. It was supposed to have a view over exit 6 and 7 but the camera failed. The activities and actions during the evacuation of the occupants are shown in table A5.

Comments

The customers who were in this area did not start move until staff told them to. The members of staff were very effective in this area to direct people towards exits and they worked with each other very well. The staff directed most of the customers to exit 6 which leads directly to the outside of the building, instead of exit 7.

Time (second)	Customer/staff status	Activities	Actions
0	customers	browsing	
15	customers	browsing	seeking information
19	staff	moving towards exit	opening doors
22	4 member of staff	organising	directing customers to exit 6
35	staff	directing elderly woman	ignoring direction at first
38	customer	leave her basket with goods	evacuating
38	customer in wheelchair	moving towards exit 6	evacuating
57	staff	running towards exit 6	evacuating
76	staff	running towards exit 6	evacuating
102	7 members of staff	moving towards exit 6 and sweeping area	evacuating
164	security staff	search area	moving out of shot

Table A5 Summery of activities and actions of occupants captured by camera A2.

Camera position A5 - Men's wear 3, Tills

The position of this camera was in men's wear 3 department. It had a view over the tills in men's wear 3. The activities and actions during the evacuation of the occupants are shown in table A10.

Comments

There were three members of staff serving customers at the tills. The staff at the tills reacted very fast and directed customers toward exits. One customer put back her clothes before evacuating and a female customer with a trolley browsed when 74-80 seconds had elapsed after the alarm sounded. The staff did not direct her to evacuate and that delayed the evacuation of the captured area.

Time (second)	Customer/staff status	Activities	Actions
0	customers/staff	purchasing, queuing, serving	
4	staff	serving customers	responding to fire alarm
14	staff	walking into shot and directing customers towards exits	customers moving toward exits
20	staff	moving with customers to exit	evacuating
22	staff	serving last customer	closing tills
35	staff	directing customers to exits	moving towards exit
43	customers	moving towards exits	evacuating
74	customer	browsing	walking out of shot probably towards exit
88	staff	seeking	moving to help customer

Table A10 Summery of activities and actions of occupants captured by camera A5.

Camera position A4 - Men's shoes, Exit 3

The position of this camera was near exit 3 . It had a view over exit 3 in the men shoes department. The activities and actions during the evacuation of the occupants are shown in table A13.

Comments

The members of staff reacted very quickly. They were also very effective directing people towards exits. They co-operated very well with each other. It has to be comment that 130 seconds after the alarm sounded, a customer entered the store and no one stopped her.

Time (second)	Customer/staff status	Activities	Actions
0	staff	working with goods	
6	staff	working with goods	putting on a jacket
14	staff	looking around	seeking information, organising
18	staff	organising	opening doors and directing customers to exit 3
30	customers	moving towards exit 3	evacuating
73	customer with wheelchair	moving towards exit 3	evacuating
76	customer	walking	queuing at exit 3
83	security staff	assisting customer in wheelchair	evacuating via exit 3
98	staff/customers	evacuating	evacuating completed in this area
131	customer (lady)	enter store	moving towards ladies shoes
143	customer(lady)	moving towards ladies shoes	out of shot

Table A13 Summery of activities and actions of occupants captured by camera A4.

Camera position A6 - Women's shoes

The position of this camera was near exit 2. It had a view over exit 2 in the women's shoes department.. The activities and actions during the evacuation of the occupants are shown in table A14.

Comments

One member of staff tried to open the door with a swipe card i.e. de-activated and opened an alarmed door. It should be noted that staffs normally use the door and then using swipe card. When she did not succeed a customer asked the member of staff if she could open the door by emergency mechanism, which shall be used in situations like this. Most of the people were in this part of the store when the alarm sounded. Most of these people choose and was directed by staff to evacuate via exit two.

The lady who entered the store via exit 3, 130 seconds after the alarm sounded, was evacuated by staff via exit two 160 seconds after the alarm sounded i.e. 30 seconds later. Except the issues mentioned above the staff were successfully evacuating the customers in this area.

Time (second)	Customer/staff status	Activities	Actions
0	2 member of staff	working with goods	looking around, one of the staff leaves the area
5	member of staff	walking towards emergency exit	wants to open the door
12	member of staff	try to open the door by reaching for a key but she can not reach it. Door has a emergency mechanism	turns around and looking for help
20	customer	looking for information	walking towards emergency exit
24	customer	at emergency exit	wants to evacuate
27	customer	discussion with member of staff	opening door with emergency exit mechanism, customers evacuating
28	member of staff	putting her jacket on	

43	member of staff	walking out of shot	walking out of shot she is not helping or directing any customers
44	customer	browsing	browsing
46	staff	checking customers basket	directing customers to leave
54	security staff	arriving	turning the door alarm off
87	staff	searching area	directing customers evacuate
98	customer	walking to exit	long que and turning around seeking another exit
113	2 members of staff	at emergency exit	evacuating
131	customers/staff	evacuating	evacuating
135	staff	searching area	closing door
153	customer that entered store at 131 s via exit 3	walking	directed to evacuate
163	staff	moving towards emergency exit	re open the emergency door
165	customer that entered store at 131 s via exit 3	at emergency door	evacuating
172	staff	closing door	walking into store and out of shot

Table A14 Summery of activities and actions of occupants captured by camera A6.

Camera position P2 - Ladies 3, Changing room

The position of this camera was in the ladies 3 department. It had a view over the entrance to the ladies changing facility in ladies 3 department. The activities and actions during the evacuation of the occupants are shown in table A15.

Comments

During the first 20 seconds there were no reactions by the staff in this area. There were many people in the changing room and the staff directed people to the exits successfully. Staff controlled the changing room several times to be sure that it was empty.

Time (second)	Customer/staff status	Activities	Actions
0	customers/staff	trying articles of clothing	
20	staff	leaving changing room	directing customers to exit 2
23	customer	leaving changing room	moving towards exit 2
46	customer	leaving changing room	moving towards exit 2
47	security staff	walking towards exit 2	walking out of shot
57	staff	entering area	walking towards changing room and entering it
60	customer	moving towards exit 13	evacuating
85	staff	walking out of changing room (entered at 57 s)	searching for customer, leaves in direction of exit 2
93	staff	exiting changing room	evacuating
97	staff	searching and sweeping the area	evacuating via exit 2

Table A15 Summery of activities and actions of occupants captured by camera P2.

Camera position P1 - Ladies 3

The position of this camera was in the ladies 3 department. It had a view over the ladies 2 and lingerie department. The activities and actions during the evacuation of the occupants are shown in table A16.

Comments

There were many people browsing in this part of the storey. 45 seconds after the alarm sounded there were customers browsing. There was no action by the staff to direct customers to exits in this area.

Time (second)	Customer/staff status	Activities	Actions
0	customers	browsing	
13	two ladies with a child and a trolley	seeking information	discuss and converse with each other
24	customer	moving towards exit	evacuating
32	two ladies with a child and a trolley	walking	evacuating via exit 1
45	lady customer	browsing	moving towards exit 1
47	customer	walking	stops and seeking information
57	customer who stopped	moving towards exit 1	evacuating

Table A16 Summery of activities and actions of occupants captured by camera P1.

Camera position A7 - Ladies 2

The position of this camera was in the ladies 2 department. It had a view over exit 1. The activities and actions during the evacuation of the occupants are shown in table A17.

Comments

In the area covered by the camera there was only the security staff who was assisting the customers to evacuate. When 53 seconds elapsed there were still customers looking for more information and started to move because they were influenced by movement of other people.

The security staff opened the door with a swipe card instead of emergency mechanism. That is behaviour not to be used in emergency situations.

Time (second)	Customer/staff status	Activities	Actions
0	customer	conversing	moving towards exit 1
2	security staff	moving towards exit 1	door alarm off
10	security staff	at exit 1	opening doors
13	customer	moving towards exit 1	evacuating
20	security staff	directing customer	customer moving towards exit 1
53	customers	conversing and have seen everything from time 0	influenced by movement of other people, evacuating
86	customer	evacuating	evacuating completed through exit 1

Table A17 Summery of activities and actions of occupants captured by camera A7.

Camera position S9 - Main entrance, Exit 13

The position of this camera was near exit 13. It had a view over exit 13 towards entrance mall. The activities and actions during the evacuation of the occupants are shown in table A18.

Comments

This is the main access/egress door to the Marks & Spencer store. It is there for of some major concern that this door was left unattended during the evacuation. People were allowed to enter the store 48 seconds after the alarm sounded because of no presents of staff. Most of the people that entered the store after the alarm sounded was informed by other customers or staff deeper in the store to evacuate. In the entrance mall people stayed and looked curiously into the Marks & Spencer store.

Time (second)	Customer/staff status	Activities	Actions
0	customer	entering store	pausing
15	customer	entering store	walking into store
46	customer	moving towards exit	evacuating via exit 13
46	staff	walking towards exit	stop shoppers from entering store for a while
48	customers	entering store	walking into store
49-75	customers	walking towards exit 13	evacuating
85	customer	walking towards exit 13	evacuating completed
91	customer in entrance hall	curious and seeking information	looking into store
101	lady customer	walking towards entrance of store	informed en stopped by other customer
160	member of staff	inform customer in entrance hall	directing customer to evacuate entrance hall

Table A18 Summery of activities and actions of occupants captured by camera S9.

Camera position A10 - Lingerie department

The position of this camera was in the lingerie department. It had a view over the lingerie department towards the changing rooms. The activities and actions during the evacuation of the occupants are shown in table A10.

Comments

The customers who were in this area did not start move until staff told them to. The members of staff were very effective in this area to direct people towards exits. Staff successfully assisted a child and re-united it with its parents.

Time (second)	Customer/staff status	Activities	Actions
0	customers	browsing	none
3	staff	organising	informing customer to evacuate via exit 12
20	customer	moving towards exit 12	evacuating
26	lost child	trying to find parent	walking around
26	member of staff	gathering child	find the child's parent
42	customers/staff	evacuating	evacuating
64	3 customers	moving towards exit 10	evacuating
78	staff	search area	evacuating

Table A20 Summery of activities and actions of occupants captured by camera A10.

Camera position A8 - Children's wear, Exit 8

The position of this camera was in the children's wear department. It had a view over the children's wear department towards exit 8. The activities and actions during the evacuation of the occupants are shown in table A23.

Comments

There was very little activities and action by staff in this area to assist customers.

Time (second)	Customer/staff status	Activities	Actions
0	customers	browsing	
22	customers	browsing	looking up
27	customers	moving towards exit 8	opening doors and evacuating
42	staff	at exit door	evacuating
69	customer	evacuating	evacuating
78	staff	running towards exit 8	evacuating completed through exit 8

Table A23 Summery of activities and actions of occupants captured by camera A8.

Camera position P13 - Household

The position of this camera was in the household department. It had a view over the household department towards exit 10. The activities and actions during the evacuation of the occupants are shown in table A25.

Comments

The members of staff were very effective in this area to direct people towards exits and influenced on the whole evacuation process by their actions.

Time (second)	Customer/staff status	Activities	Actions
0	customers/staff	customer pushing a wheelchair	browsing
22	customers/staff	organising and seeking information	staff directing customers to evacuate through exit 12
35	customers	walking towards exit 10	evacuating
55	staff	looking for customers to direct to exits	sweeping area
101	staff/fire staff	sweeping area with fire-extinguisher	evacuating through exit

Table A25 Summery of activities and actions of occupants captured by camera P13.

Camera position A9 Household, Exit 12

The position of this camera was in the household department. It had a view over the household department towards exit 12. The activities and actions during the evacuation of the occupants are shown in table A26.

Comments

The well-trained staff was very active directing customers to exits and sweeping the area. Fire staff was also sweeping the area searching for something abnormal.

Time (second)	Customer/staff status	Activities	Actions
0	customers	browsing	browsing
10	customers/staff	organising and seeking information	staff directing customers to evacuate through exit 12
35	customers	walking towards exit 10	evacuating
55	staff	looking for customers to direct to exits	sweeping area
75	staff	sweeping area	directing customers
106	staff/fire staff	sweeping area with fire-extinguisher	evacuating through exit

Table A26 Summery of activities and actions of occupants captured by camera A9.

Camera position P14 - Customer service

The position of this camera was at the customer services.. It had a view over the customer services and exit 11. The activities and actions during the evacuation of the occupants are shown in table A27.

Comments

In the reception of the customer services there were four members of staff serving customers. The staff did not react on the fire alarm until one member of staff entered the customer services from the store and directed them to evacuate. That happened almost 50 seconds after fire alarm sounded. There was no one who tried to seek more information about what was happening. The staff behind the desk did not assist customers, so when the customers left they did not know where the nearest exit was. Instead of entering the nearest exit half a metre away the customers re-entered the store.

The location of the customer services might be one reason that the staff did not react because they could not see into the store. The staff should have known how to react and respond to the alarm.

Time (second)	Customer/staff status	Activities	Actions
0	Customers/staff	purchasing, serving	customers looking up and leave area
20	customer	completing business	leaving area
20	staff	looking for more information	conversing with each other
46	member of staff	directing other staff and customers to leave	evacuating
70	member of staff/fire staff	entering area	searching for fire and evacuating later via exit 11
104	staff	walking out from door behind desk	evacuating

Table A27 Summery of activities and actions of occupants captured by camera P14.

Appendix B

Examples of summery of occupant activities, action and observations distilled from analysis of videotapes in Mark & Spencer, Belfast.

Introduction

In this appendix examples of the analysis of the videotaped evacuation is summarised and presented for each camera location and field of view. The use of video gives the pre-movement times, and occupants commitment to their behaviour and data that will be useful for the input in computer model Simulex. The order of cameras is as shown on the videotapes. The plan and camera position of the first floor is shown in figure B1, B2 and B3.

The plan and camera position of the Belfast store

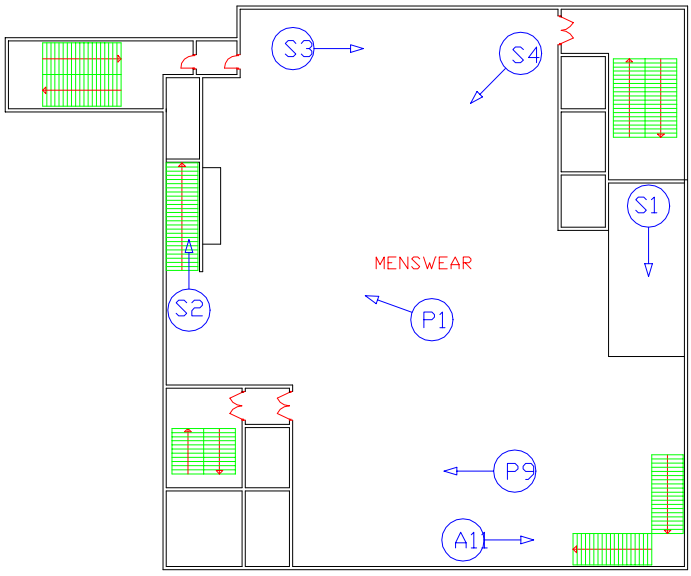


Figure B1 The plan and camera position of the first floor at Marks & Spencer, Belfast

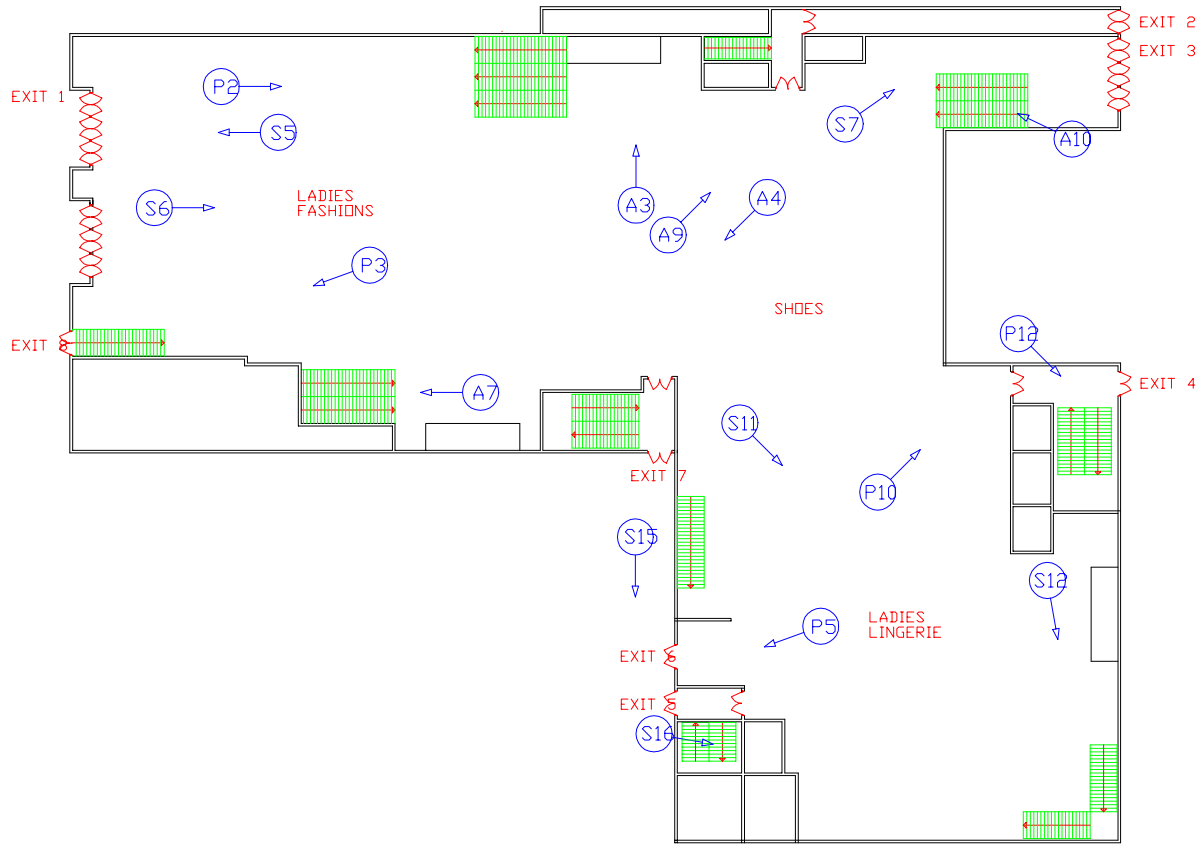


Figure B2 The plan and camera position of the ground floor at Marks & Spencer, Belfast

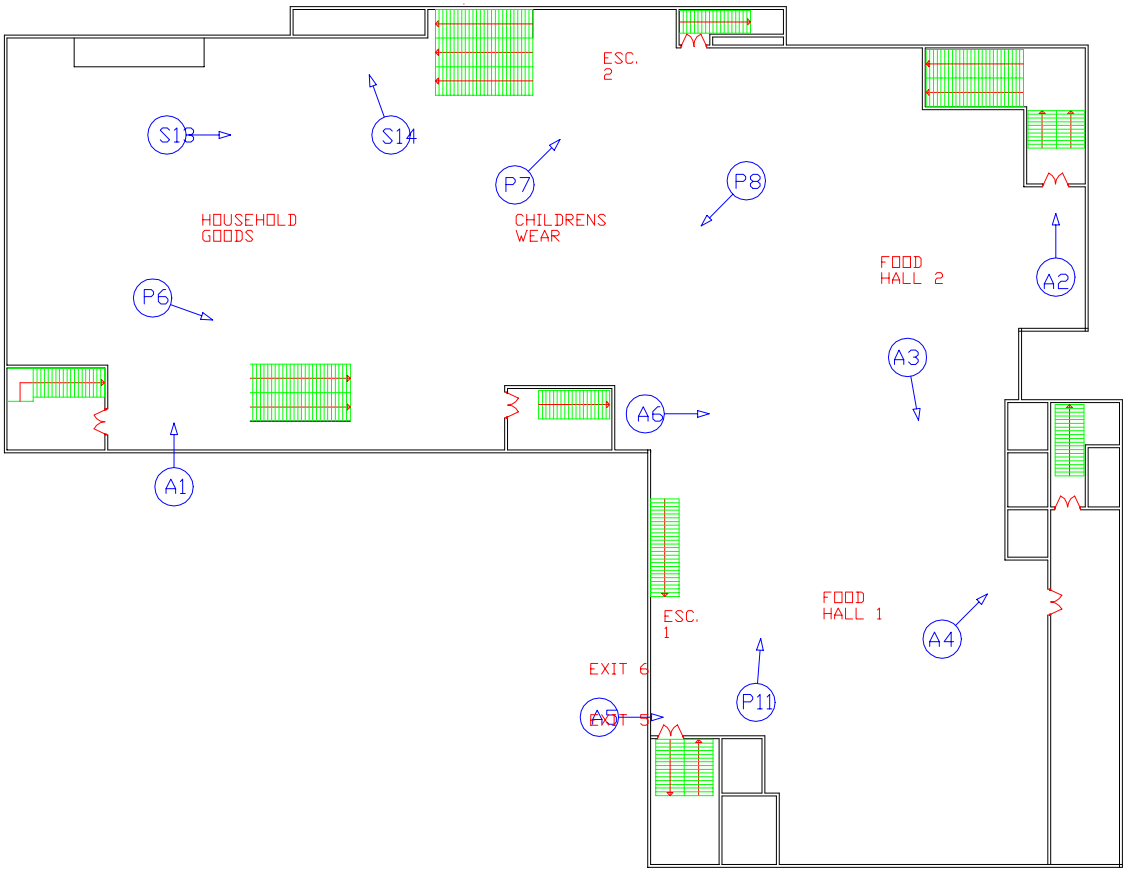


Figure B3 The plan and camera position of the basement floor at Marks & Spencer, Belfast

Camera position S3 - Men's wear Department, First floor

The camera position S3 was at the men's wear at first floor. It had a view of the entrance to stairwell 2. The activities and actions during the evacuation of the occupants are shown in table B2.

Comments

There were one member of staff and two customer captured by camera S3.The area was swept once by the staff. Stairwell 2 was not used.

Time (second)	Customer/staff status	Activities	Actions
0	Customer	looking at clothes	
15	Customer	look up	seeking information
21	Customer	browsing	browsing
45	Member of staff	moving out of shot	evacuating
110	Security staff	sweeping area	searching for customers
110	Security staff	moving out of shot	evacuating

Table B2 Summery of activities and actions of occupants captured by camera S3.

Camera position S1 - Men's wear Department, First floor

The camera position S1 was at the men's wear at first floor. It had a view over the customer service. The activities and actions during the evacuation of the occupants are shown in table B4.

Comments

There were four members of staff and two customers captured by camera S1. The staff swept the area twice. Customers moved towards escalators or stairwells on the other side of the men's wear, instead of using stairwell 9 that was the closest stairwell. The area was evacuated very quickly because of the fast reaction by staff.

Time (second)	Customer/staff status	Activities	Actions
0	Customers, staff	serving customers	serving customers
7	Staff	seeking information	looking around
14	Staff	organising	directing customers towards exit
20	Customers and staff	moving towards exit	evacuating
27	-	area is evacuated	
48	Staff	sweeping area	evacuating
71	Staff	sweeping area	evacuating and area is cleared

Table B4 Summery of activities and actions of occupants captured by camera S1.

Camera position P9 - Men's wear Department, First floor

The camera position P9 was at the men's wear at first floor. It had a view towards the lift and stairwell 3. The activities and actions during the evacuation of the occupants are shown in table B5.

Comments

There were two members of staff operating in the area captured by camera P9. Customers moved towards escalators or stairwells. The area was evacuated very quickly because of the fast reaction by staff. It shall be noted that most customers did not move to the nearest exit. The lift caused a delay in the evacuation of this floor because it was busy on other floors. People waited, but when the lift did not come when it was called the customers chose another ways.

Time (second)	Customer/staff status	Activities	Actions
0	Customers	browsing	browsing
0	Customer with push chair	enter the men's wear via lift	browsing
2	Staff	seeking information	looking around
4	Staff	moving towards an old lady customer	directing her towards exit
10	Customers	moving towards exit	evacuating
10	Customer with push chair	moving towards lift	evacuating
33	Customer with push chair	waiting for the lift but it does not come	moving towards escalators
80	Two customers	waiting for the lift but it does not come	moving towards escalators
105	The two customers at 80 seconds	evacuating	evacuating via escalators
127	Customers	evacuating	evacuating via stairwell 3 and escalators

Table B5 Summery of activities and actions of occupants captured by camera P9.

Camera position A11 - Men's wear Department, First floor

The camera position A11 was at the men's wear at first floor. It had a view of the stairwell 4 down towards the ground floor. The activities and actions during the evacuation of the occupants are shown in table B7.

Comments

There was only one customer that used stairwell four as an escape route down to ground floor.

Time (second)	Customer/staff status	Activities	Actions
21	Customer	walking down the stairwell	evacuating

Table B7 Summery of activities and actions of occupants captured by camera A11.

Camera Position A1 - Household Department, Basement

The camera position A1 was at the household goods in the basement near stairwell 6. It had a view of the household goods and part of stairwell 6. The activities and actions during the evacuation of the occupants are shown in table B8.

Comments

There were very few persons in this part of the store. It shall be noted that only one customer used stairwell six to escape up to ground floor and then out of the building. The security staff came to the basement via stairwell 6 and swept the area.

Time (second)	Customer/staff status	Activities	Actions
0	Customers	in background, browsing	
1	Customers	browsing	
85	Customers	moving towards stairwell six	evacuating
191	Security	searching and sweeping	moving out of shot

Table B8 Summery of activities and actions of occupants captured by camera A1.

Camera Position P7 - Children's wear Department, Basement

The camera position P7 was at the children's wear department in the basement. It had a view over the escalators. The activities and actions during the evacuation of the occupants are shown in table B12.

Comments

There was a lot of activity in the area captured by camera P7 before the alarm sounded. Staff reacted very quickly when the alarm sounded and they directed customers quickly towards escalators. There were customers who needed the direction from the staff to start evacuate. There was for examples the male with the newspaper who sat near the escalator who needed the signal to move. Some of the customers had to be directed twice to start evacuate.

It should be noted that no one used stairwell seven to evacuate. It might depend on the fact that the staff directed the customers only to the escalators. One of the escalators was switched off and caused that queuing on the other one. No one ascended the escalator that was switched off.

Time (second)	Customer/staff status	Activities	Actions
0	Two customers (male and female)	sitting beside escalator, male reading newspaper	
3	Lady with child in push chair and other child by the hand	walking towards escalator	looking for information, continues walking
2	Security guard	walking towards the escalator	reacting and moving up to ground floor via the escalator
4	Customers		entering the basement via escalators
6	Customer	seeking information	looking at the guard on his way up the escalator
24	Customers	walking towards the escalator	evacuating via escalator
24	Lady with push chair and child	walking, moving towards escalator	evacuating
27	Staff	moving towards customers, sitting	directing them to escalator

		beside escalator	
27	Customer (lady)	walking towards escalator	evacuating via escalator
29	Customers	walking towards escalator	evacuating
39	Customer, (male who was reading his newspaper sitting by escalator)	rising (being directed by staff earlier)	walking to the end of the queue and waiting for his turn to evacuate via escalator
72	Staff	entering the area captured by the camera	managing the evacuation via the escalator
89	Customer	placing her bag of goods on one seat next to the escalator and then going back to the queue	queuing at escalator waiting to evacuate, queuing
120	Customer	Lady with push-chair and two children	ascending the escalator, evacuating
180	Customer (male who was sitting at the escalator)	ascending the escalator with the assistance of staff	evacuating
200	Security staff	entering the area captured by the camera	sweeping and searching the area

Table B12 Summery of activities and actions of occupants captured by camera P7.

Camera Position A6 - Food hall Department, Basement

The camera position A6 was at the tills in the food hall. It had a view of the tills and the beginning of escalator 1 at the basement. The activities and actions during the evacuation of the occupants are shown in table B14.

Comments

The staff reacted very quickly. The tills were closed 30 seconds after alarm sounded. It must be noted that none of the customers even looked at the escalator that was the nearest escape route during the first 60 seconds. It might depend on the fact that members of staff in the beginning of the evacuation directed people to other stairways or escalators. One member of staff switched the downward escalator to upward mode, which was good management and then directed the customers to the escalator that was nearest.

Time (second)	Customer/staff status	Activities	Actions
0	Customers Staff	purchasing, serving, packing, queuing	
	Staff	seeking information,	investigating
20	Staff	directing customers to leave	managing evacuation of area
35	Staff	closing tills	directing customer to evacuate
57	Customers	people passing escalator without using it	evacuating via stairwell one
68	Staff	staff member switching downward escalator to upward mode	directing customer to evacuate
111	Last customer	ascending	evacuating via the escalator
215	Staff	Entering area	Sweeping and Searching

Table B14 Summery of activities and actions of occupants captured by camera A6.

Camera position P11 - Food hall Department, Basement

The camera position P11 was at the tills in the food hall in the basement. It had a view over the tills. The activities and actions during the evacuation of the occupants are shown in table B15.

Comments

The customers and staff that were purchasing respectively serving were seeking for more information in the beginning. The members of staff organised the evacuation. Most customers and staff that were evacuating through the tills used the escalator 1 next to the tills. The fast reaction from staff and the direction of customer by staff to exits influenced the fast evacuation in this space.

Time (second)	Customer/staff status	Activities	Actions
0	Customers and staff members at tills	Customers is purchasing and queuing Staff is serving	
7	Customer and staff at tills	purchasing, serving	seeking information
17	Staff at tills	directing activities to customers	tills closing
24	Tills closed, except one	beginning to move customers towards exit	customers evacuating
45	Staff	all tills closed	
95	Staff	sweeping area	searching for persons

Table B15 Summery of activities and actions of occupants captured by camera P11.

Camera position A3 - Food hall Department, Basement

The camera position A3 was in the food hall in the basement. It had a view over one of the isles in the food hall towards stairwell 2. The activities and actions during the evacuation of the occupants are shown in table B16.

Comments

Customers and staff were still browsing after the alarm sounded. 20 seconds elapsed until staff started to seek after information. Customers ignored the alarm and were interrupted by staff 44 seconds after the alarm sounded. When the staff became aware of the situation they were very active to evacuate the area. Most of the customers used stairwell 2 as an escape route to ground floor.

Time (second)	Customer/staff status	Activities	Actions
0	Customers and staff	browsing	no reaction to the alarm
21	Staff	seeking information	looking around
45	Staff	organising	directing activities to customers
50	Customers	moving towards different exits	customers evacuating
80	Customer	retrieve goods	evacuating
100	Staff	directing customers to evacuate	customers evacuating
110	Wheelchair party	assisted by member of staff	evacuating via stairwell two
124	Staff	sweeping area	directing customer
237	Security staff	sweeping area	searching for people

Table B16 Summery of activities and actions of occupants captured by camera A3.

Camera position A2 - Food hall Department, Basement

The camera position A2 was in the food hall in the basement of the building. It had a view over stairwell 8. The activities and actions during the evacuation of the occupants are shown in table B17.

Comments

Customers were browsing for a long time before they were reacted to the alarm and started to evacuate. The security guard did not warn people when he was aware about the alarm and ran up the stairwell 8. After 34 seconds a lady entered the food hall via stairwell 8 and she was not stopped. During the evacuation a lady re-entered the store which influenced the behaviour of a lady who came after. The influenced woman started to follow the re-entered lady but was directed back to stairwell 8 by member of staff.

Time (second)	Customer/staff status	Activities	Actions
0	Customer, staff	browsing	
8	Security staff,	aware of alarm	running up stairwell 8
34	Customer	entering food hall via stairwell 8	browsing
35	Customer	leaving basement	walking up stairwell 8
47	Customers	browsing	browsing
53	Customers	moving towards stairwell 8	evacuating
70	Customer that entered at 34 seconds	moving towards stairwell 8	evacuating via stairwell 8
80	Customer	entering stairwell 8, changing her mind and re-entering basement	walking into the food hall
85	Customer	following the lady, who re-entered the store at 80 seconds	directed by staff to stairwell 8
140	Staff	directing customer to	customer evacuating

		stairwell 8	

Table B17 Summery of activities and actions of occupants captured by camera A2.

Camera position P4 - Shoes, Ground floor

The camera position P4 was at the shoes department at the ground floor. It had a view towards the ladies fashions department. The activities and actions during the evacuation of the occupants are shown in table B26.

Comments

The staff had a lot of influence on the customers. They changed the route for them and let them exit via exit 7.

Time (second)	Customer/staff status	Activities	Actions
0	Four customers	browsing	looking at goods
30	Staff	directing customers	ignoring direction at first
36	Customers	Walking towards exit	evacuating
53	Customer	Exiting via exit 7	Evacuating
85	Customers	Moving towards exit 3 but called for exit 7	Changing direction and evacuating through exit 7
105	Last customer	Evacuating	Exit the building

Table B26 Summery of activities and actions of occupants captured by camera P4.

Camera position A9 - Shoes, Ground floor

The camera position A9 was at the shoes department at the ground floor. It had a view towards the ladies fashions department. The activities and actions during the evacuation of the occupants are shown in table B27.

Comments

The staff did not direct any customer towards the emergency exit leading to final exit 2.The result was that no customer used the exit. The staff was active in this part of the store.

Time (second)	Customer/staff status	Activities	Actions
0	Customer	Browsing	Seeking information
13	Customers	Discussing what to do	evacuating
16	Customer with pushchair	Seeking information	Looking around
26	Customer	Moving towards exit	Evacuating
30	Staff	Directing people towards exit 1 and exit 3	Customers evacuating
75	Last customer	Walking out of shot	Evacuating

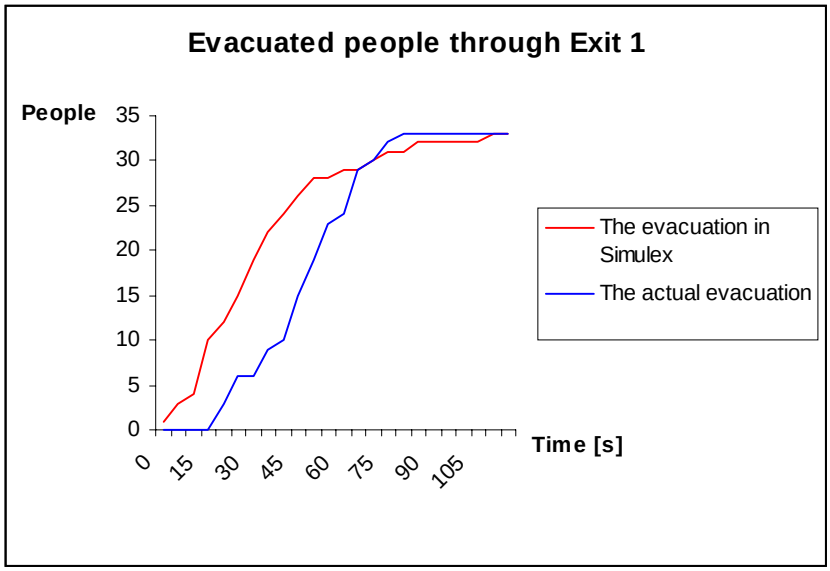
Table B27 Summery of activities and actions of occupants captured by camera A9.

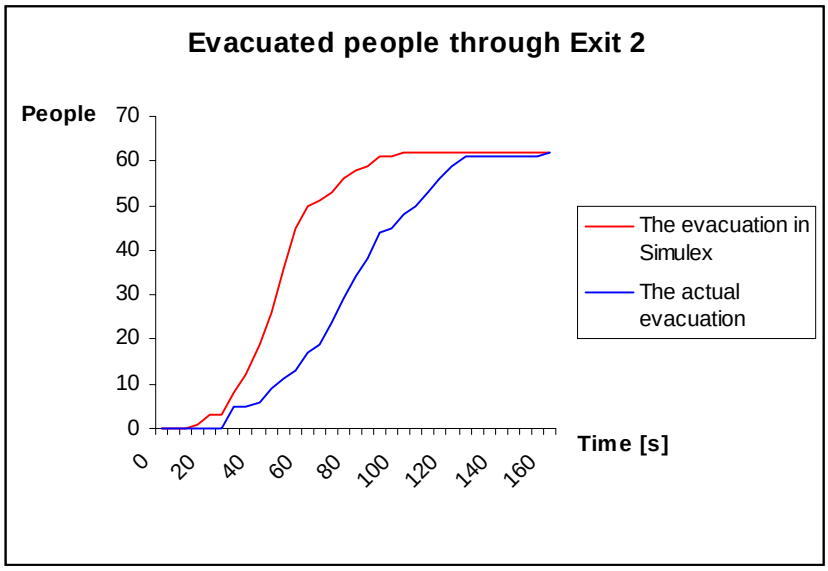
APPENDIX C

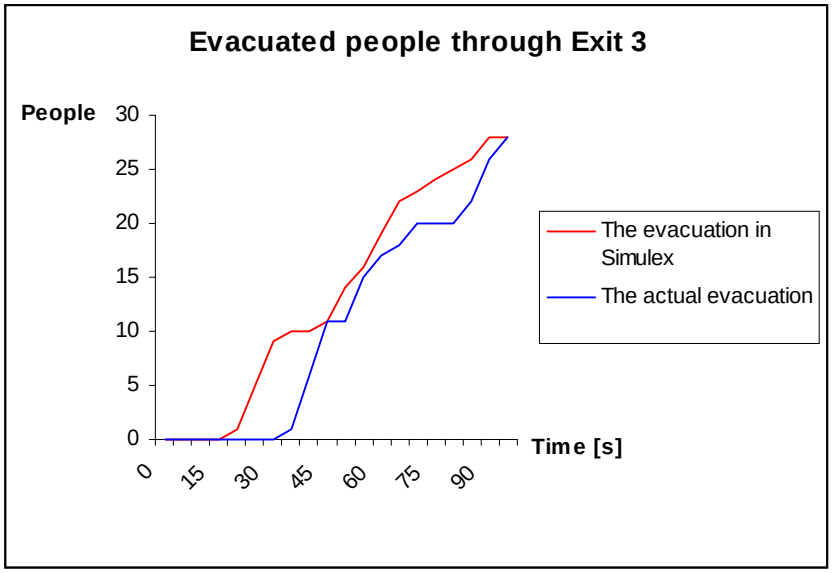
COMPARISION BETWEEN SIMULEX EVACUATION AND THE ACTUAL EVACUATION

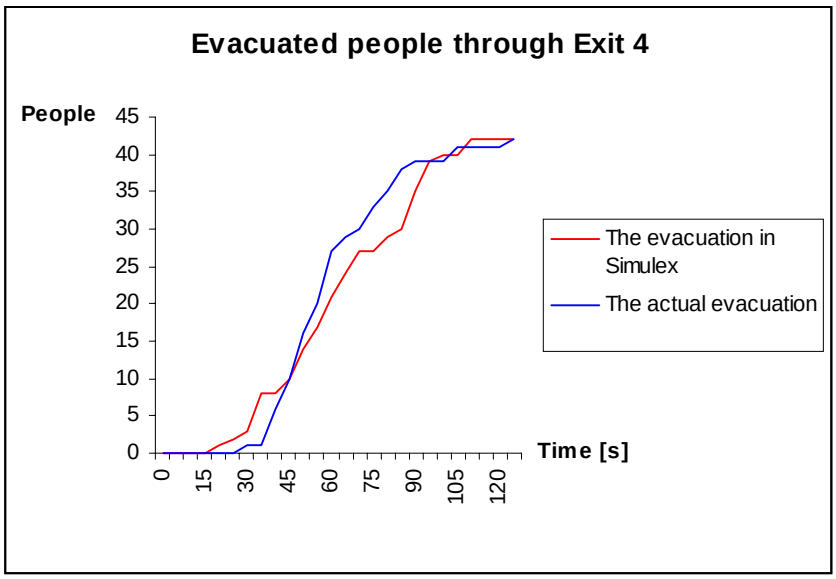
THE FLOW RATES THROUGH DIFFERENT EXITS.

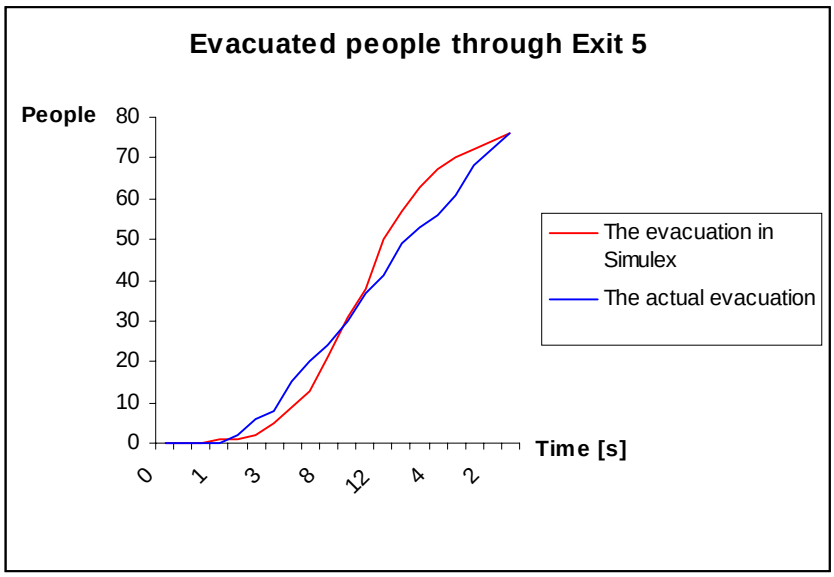
SPRUCEFIELD STORE

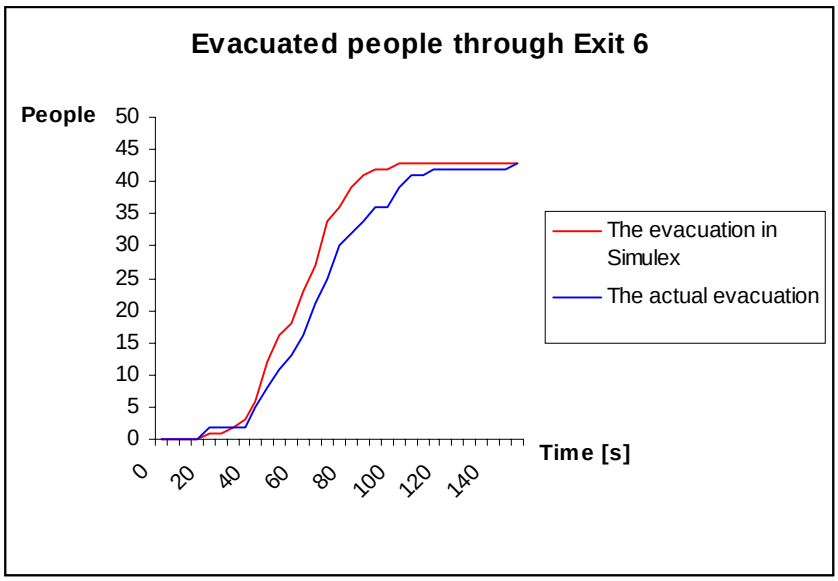

Evacuated people through Exit 1
People
35
30
25
20
15
10
5
0
0
15
30
45
60
75
90
105
Time [s]
The evacuation in Simulex
The actual evacuation

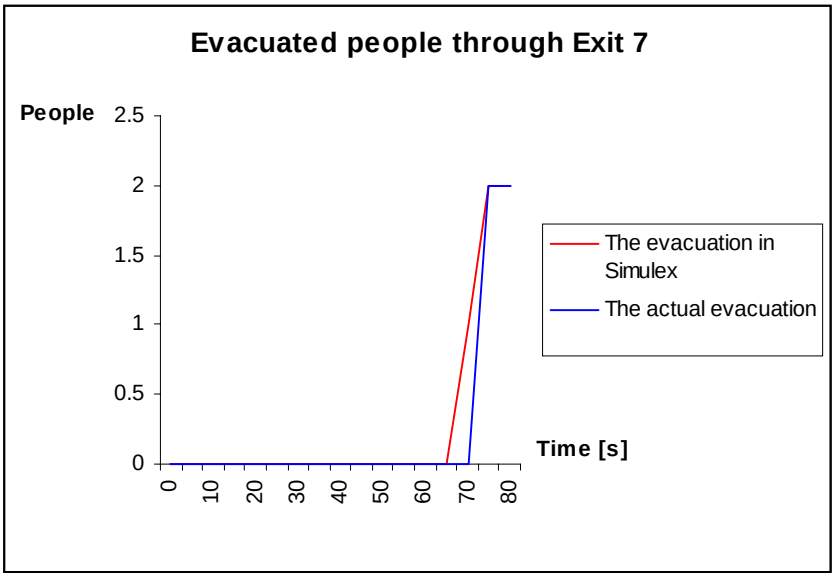

Evacuated people through Exit 2
People
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
Time [s]
The evacuation in Simulex
The actual evacuation

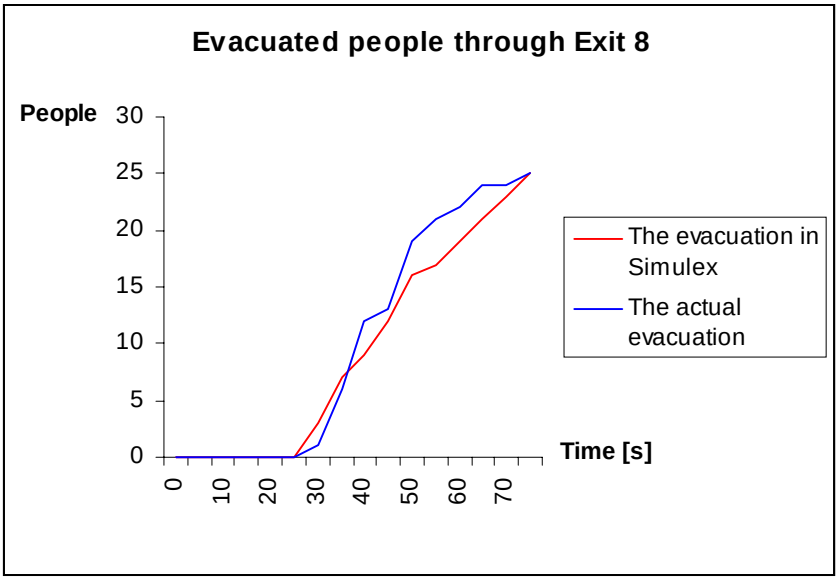

Evacuated people through Exit 3
People
30
25
20
15
10
5
0
0
15
30
45
60
75
90
Time [s]
The evacuation in Simulex
The actual evacuation

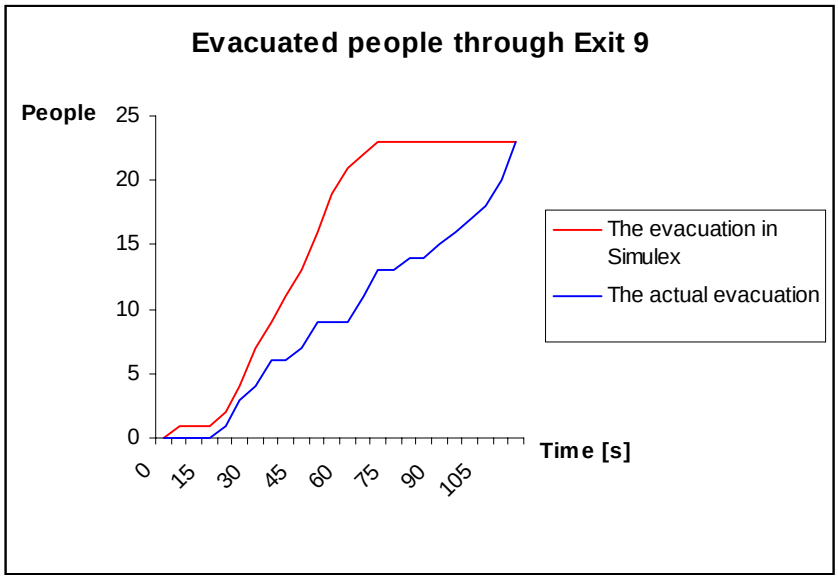

Evacuated people through Exit 4
People
45
40
35
30
25
20
15
10
5
0
0
15
30
45
60
75
90
105
120
Time [s]
The evacuation in Simulex
The actual evacuation

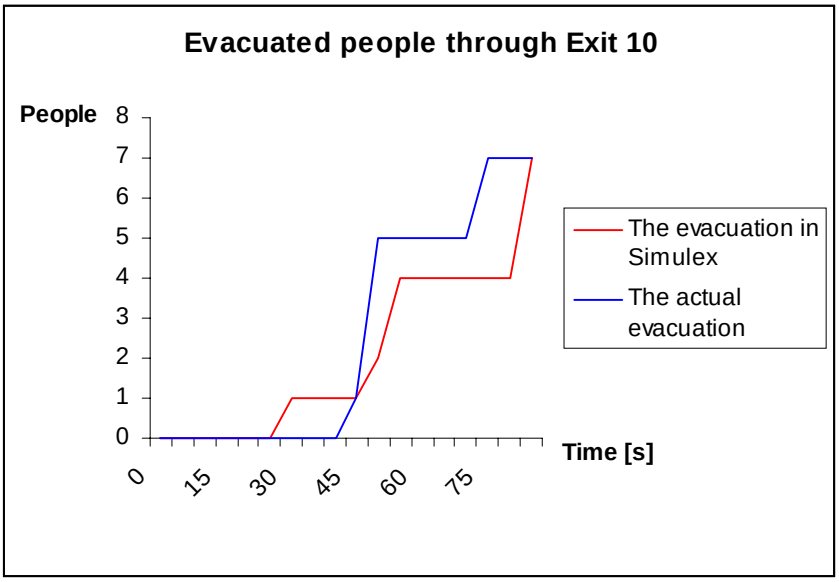

Evacuated people through Exit 5
People
80
70
60
50
40
30
20
10
0
0
1
3
8
12
4
2
Time [s]
The evacuation in Simulex
The actual evacuation

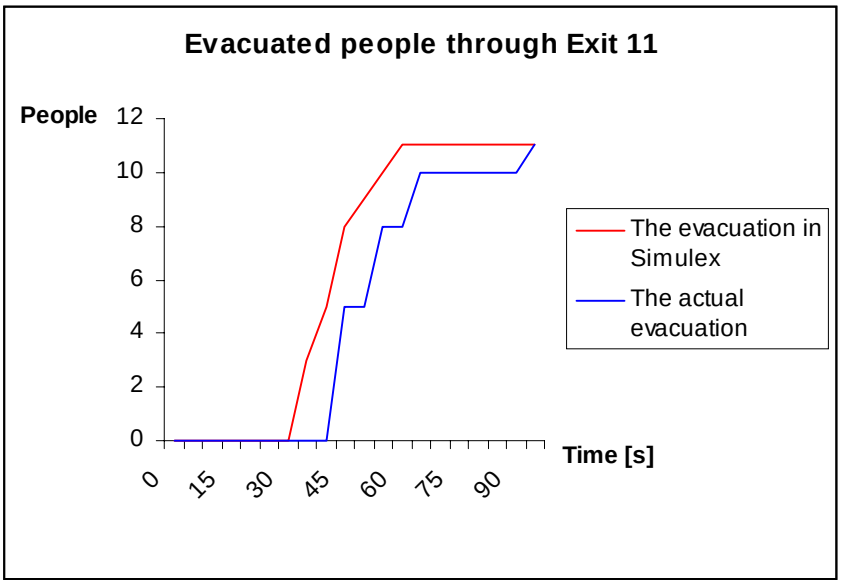

Evacuated people through Exit 6
People
50
45
40
35
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140
Time [s]
The evacuation in Simulex
The actual evacuation

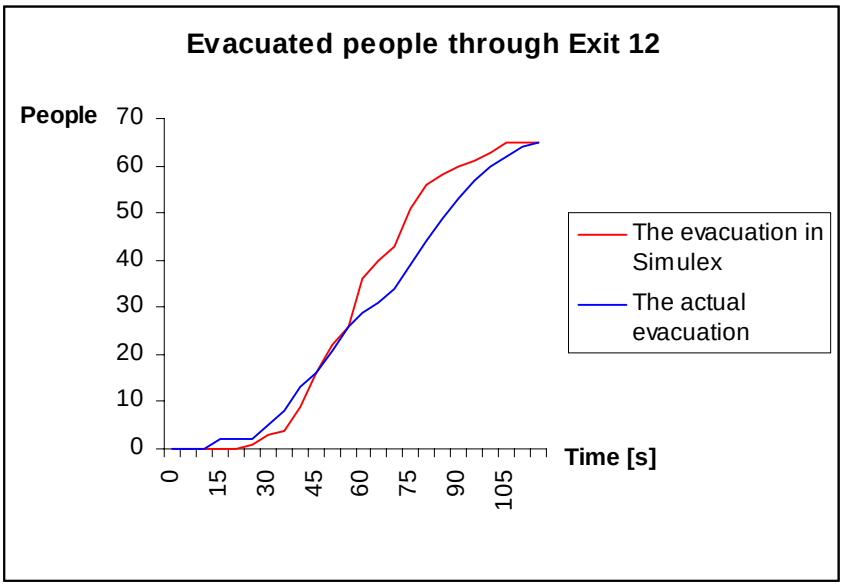

Evacuated people through Exit 7
People
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
80
Time [s]
The evacuation in Simulex
The actual evacuation

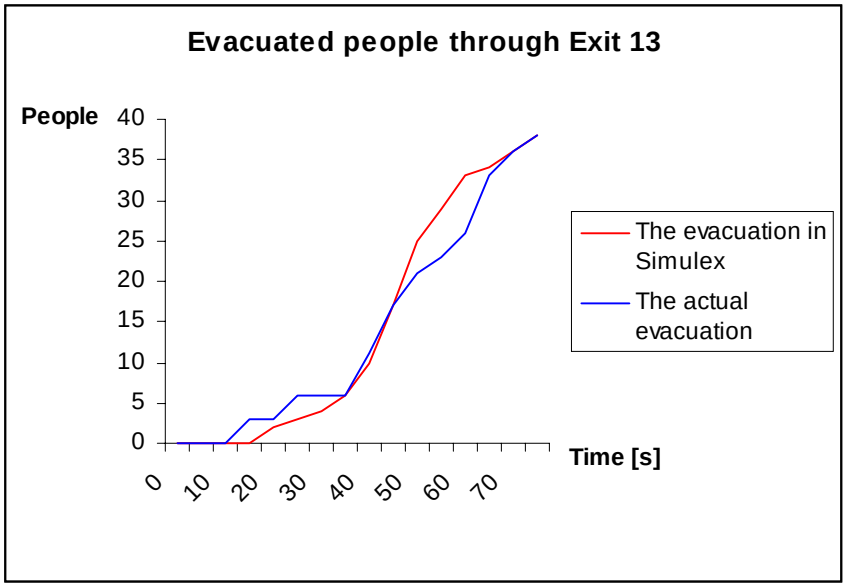

Evacuated people through Exit 8
People
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
Time [s]
The evacuation in Simulex
The actual evacuation

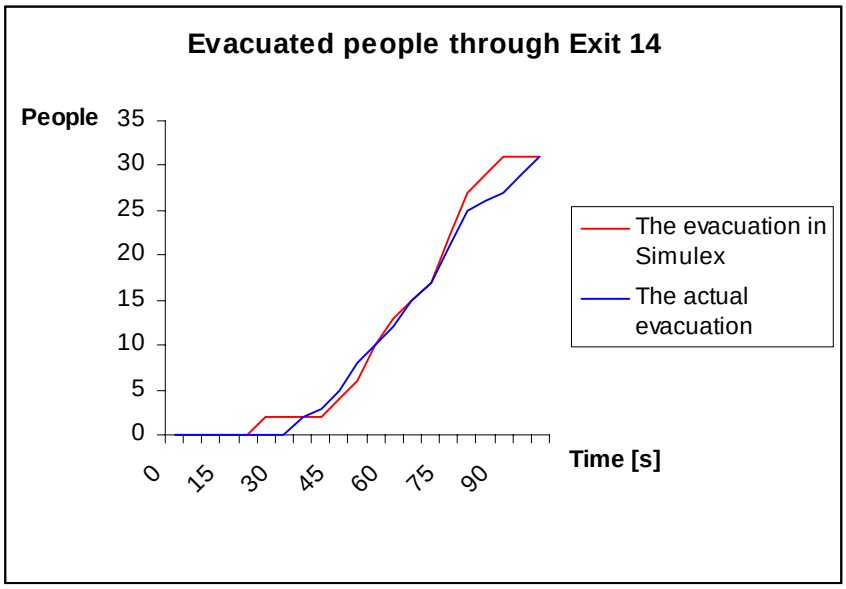

Evacuated people through Exit 9
People
25
20
15
10
5
0
0
15
30
45
60
75
90
105
Time [s]
The evacuation in Simulex
The actual evacuation


Evacuated people through Exit 10
People
8
7
6
5
4
3
2
1
0
0
15
30
45
60
75
Time [s]
The evacuation in Simulex
The actual evacuation

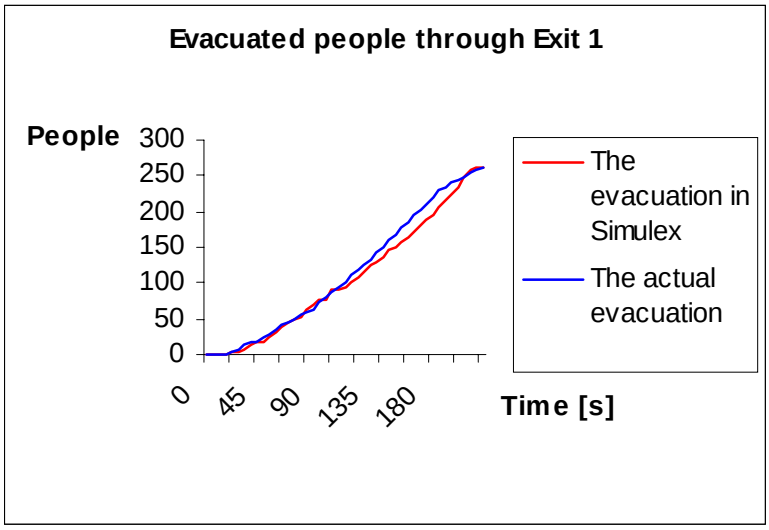

Evacuated people through Exit 11
People
12
10
8
6
4
2
0
0
15
30
45
60
75
90
Time [s]
The evacuation in Simulex
The actual evacuation

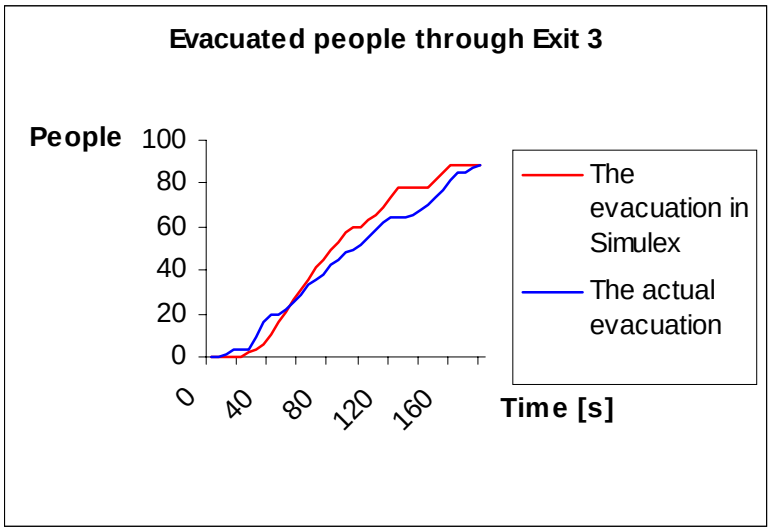

Evacuated people through Exit 12
People
70
60
50
40
30
20
10
0
0
15
30
45
60
75
90
105
Time [s]
The evacuation in Simulex
The actual evacuation

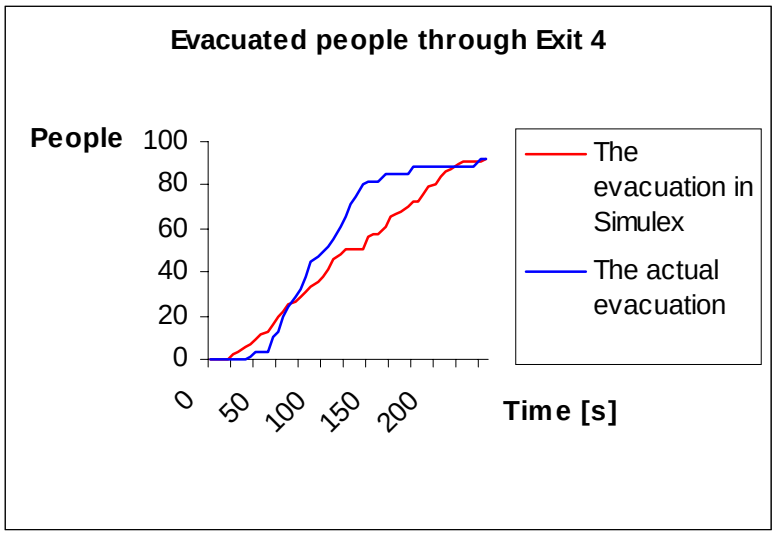

Evacuated people through Exit 13
People
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
Time [s]
The evacuation in Simulex
The actual evacuation

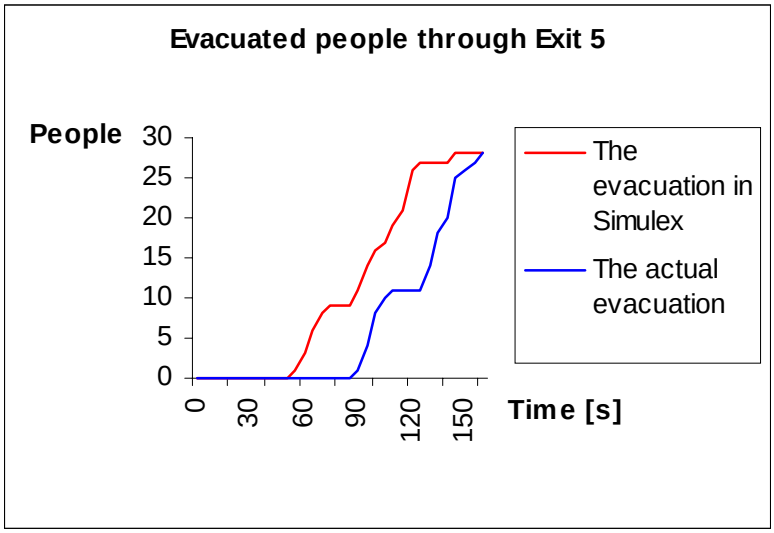

Evacuated people through Exit 14
People
35
30
25
20
15
10
5
0
0
15
30
45
60
75
90
Time [s]
The evacuation in Simulex
The actual evacuation

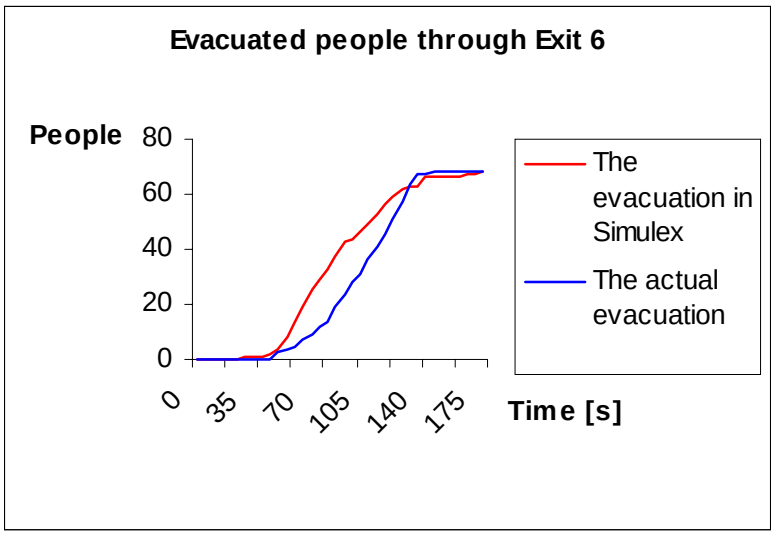
BELFAST STORE

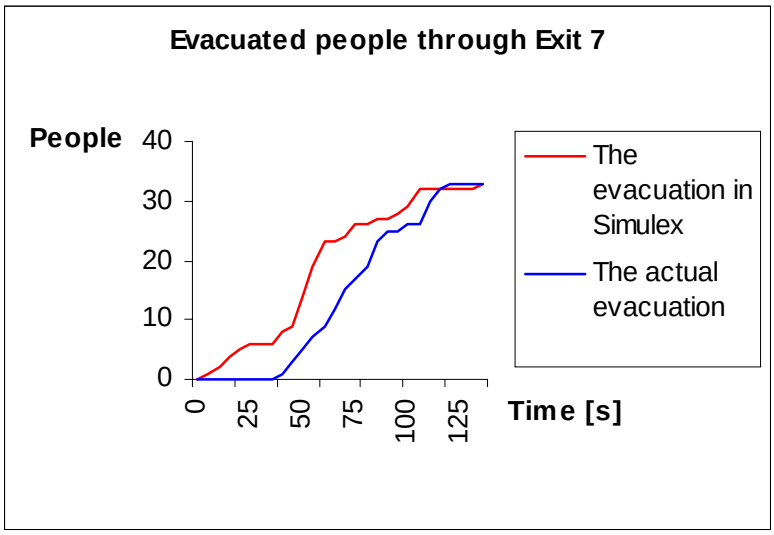

Evacuated people through Exit 1
People
300
250
200
150
100
50
0
0
45
90
135
180
Time [s]
The evacuation in Simulex
The actual evacuation


Evacuated people through Exit 3
People
100
80
60
40
20
0
0
40
80
120
160
Time [s]
The evacuation in Simulex
The actual evacuation


Evacuated people through Exit 4
People
100
80
60
40
20
0
0
50
100
150
200
Time [s]
The evacuation in Simulex
The actual evacuation


Evacuated people through Exit 5
People
30
25
20
15
10
5
0
0
30
60
90
120
150
Time [s]
The evacuation in Simulex
The actual evacuation


Evacuated people through Exit 6
People
80
60
40
20
0
0
35
70
105
140
175
Time [s]
The evacuation in Simulex
The actual evacuation


Evacuated people through Exit 7
People
40
30
20
10
0
0
25
50
75
100
125
Time [s]
The evacuation in Simulex
The actual evacuation

APPENDIX D

The distribution of occupants by department in each store

Sprucefield store

Distribution in the store, 486 occupants

Department	Exit 1	Exit 2	Exit 3	Exit 4	Exit 5	Exit 6	Exit 7
Food hall	3	0	1	27	76	37	1
Men's wear 1	1	0	9	5	0	0	0
Men's wear 2	0	0	5	3	0	0	0
Men's wear 3	0	0	5	2	0	0	1
Men's shoes	0	3	0	0	0	0	0
Ladies shoes/hosiery	1	31	1	0	0	0	0
Ladies 1	9	6	1	0	0	3	0
Ladies 2	13	11	3	0	0	0	0
Ladies 3	6	11	3	0	0	0	0
Lingerie	0	0	0	2	0	3	4
Children's shoes	0	0	0	0	0	0	2
Children's wear	0	0	0	2	0	0	8
Household	0	0	0	2	0	0	0

Department	Exit 8	Exit 9	Exit 10	Exit 11	Exit 12	Exit 13	Exit 14
Food hall	0	0	0	0	0	0	28
Men's wear 1	0	0	0	0	0	0	0
Men's wear 2	0	0	0	0	0	0	0
Men's wear 3	0	0	1	0	0	0	0
Men's shoes	0	0	0	0	0	0	0
Ladies shoes/hosiery	0	0	1	0	0	2	0
Ladies 1	0	0	2	0	7	13	1
Ladies 2	2	0	1	0	0	12	0
Ladies 3	0	0	2	0	0	5	0
Lingerie	0	0	0	0	140	5	0
Children's shoes	4	4	0	0	0	0	1
Children's wear	19	19	0	0	0	0	0
Household	0	0	1	11	43	1	1

Distribution in the store, 1458 occupants

Department	Exit 1	Exit 2	Exit 3	Exit 4	Exit 5	Exit 6	Exit 7
Food hall	9	0	3	81	228	111	2
Men's wear 1	3	0	27	15	0	0	0
Men's wear 2	0	0	15	9	0	0	0
Men's wear 3	0	0	15	6	0	0	2
Men's shoes	0	9	0	0	0	0	0
Ladies shoes/hosiery	3	93	3	0	0	0	0
Ladies 1	27	18	3	0	0	9	0
Ladies 2	39	33	9	0	0	0	0
Ladies 3	18	33	9	0	0	0	0
Lingerie	0	0	0	6	0	9	12
Children's shoes	0	0	0	0	0	0	6
Children's wear	0	0	0	6	0	0	24
Household	0	0	0	6	0	0	0

Department	Exit 8	Exit 9	Exit 10	Exit 11	Exit 12	Exit 13	Exit 14
Food hall	0	0	0	0	0	0	84
Men's wear 1	0	0	0	0	0	0	0
Men's wear 2	0	0	0	0	0	0	0
Men's wear 3	0	0	3	0	0	0	0
Men's shoes	0	0	0	0	0	0	0
Ladies shoes/hosiery	0	0	3	0	0	6	0
Ladies 1	0	0	6	0	21	39	3
Ladies 2	6	0	3	0	0	36	0
Ladies 3	0	0	6	0	0	15	0
Lingerie	0	0	0	0	420	15	0
Children's shoes	12	12	0	0	0	0	3
Children's wear	57	57	0	0	0	0	0
Household	0	0	3	33	129	3	3

Belfast store

Distribution in the store, 1710 occupants

Department	Exit 1		Exit 2		Exit 3	
	<60 years	Elderly	<60 years	Elderly	<60 years	Elderly
Food hall	255	138	0	0	86	46
Menswear	20	11	0	0	7	4
Household goods	5	3	0	0	2	1
Ladies fashions	102	55	0	0	34	18
Shoes	61	33	0	0	21	11
Ladies lingerie	61	33	0	0	21	11
Children's wear	5	3	0	0	2	1

Department	Exit 4		Exit 5		Exit 6	
	<60 years	Elderly	<60 years	Elderly	<60 years	Elderly
Food hall	90	48	27	15	66	36
Menswear	7	4	2	1	5	3
Household goods	2	1	1	0	1	1
Ladies fashions	36	19	11	6	27	14
Shoes	22	12	7	4	16	9
Ladies lingerie	22	12	7	4	16	9
Children's wear	2	1	1	0	1	1

Department	Exit 7		Exit 8	
	<60 years	Elderly	<60 years	Elderly
Food hall	32	17	0	0
Menswear	3	1	0	0
Household goods	1	0	0	0
Ladies fashions	13	7	0	0
Shoes	8	4	0	0
Ladies lingerie	8	4	0	0
Children's wear	1	0	0	0

Distribution in the store, 570 occupants

Department	Exit 1		Exit 2		Exit 3	
	<60 years	Elderly	<60 years	Elderly	<60 years	Elderly
Food hall	85	46	0	0	29	15
Menswear	7	4	0	0	2	1
Household goods	2	1	0	0	1	0
Ladies fashions	34	18	0	0	11	6
Shoes	20	11	0	0	7	4
Ladies lingerie	20	11	0	0	7	4
Children's wear	2	1	0	0	1	0

Department	Exit 4		Exit 5		Exit 6	
	<60 years	Elderly	<60 years	Elderly	<60 years	Elderly
Food hall	30	16	9	5	22	12
Menswear	2	1	1	0	2	1
Household goods	1	0	0	0	0	0
Ladies fashions	12	6	4	2	9	5
Shoes	7	4	2	1	5	3
Ladies lingerie	7	4	2	1	5	3
Children's wear	1	0	0	0	0	0

Department	Exit 7		Exit 8	
	<60 years	Elderly	<60 years	Elderly
Food hall	11	6	0	0
Menswear	1	0	0	0
Household goods	0	0	0	0
Ladies fashions	4	2	0	0
Shoes	3	1	0	0
Ladies lingerie	3	1	0	0
Children's wear	0	0	0	0